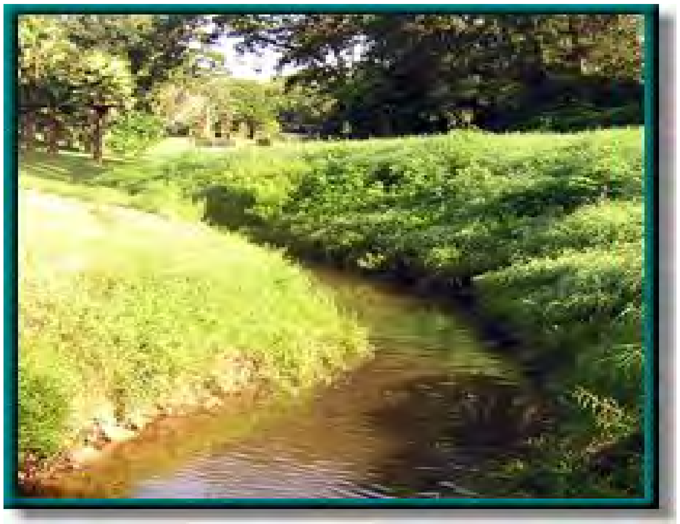
TECHNICAL SUPPORT DOCUMENT: BACTERIA TOTAL MAXIMUM DAILY LOADS FOR NEW/ADDITIONAL LISTINGS IN THE HOUSTON METRO AREA, HOUSTON, TEXAS (1007T_01, 1007U_01, 1007S_01, 1007V_01, 1017C_01 AND 1007A_01)



Prepared for:

TEXAS COMMISSION ON ENVIRONMENTAL QUALITY

TCEQ

Prepared by:

University of Houston

PARSONS

MARCH 2012

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ACRONYMS AND ABBREVIATIONS

ASAE	American Society of Agricultural Engineers
COH	City of Houston
C-CAP	Coastal Change Analysis Program
CAFO	concentrated animal feeding operation
CFR	Code of Federal Regulations
cfs	cubic feet per second
counts	colony forming unit
CN	curve number
dL	deciliter
DMR	discharge monitoring report
E. coli	Escherichia coli
EMC	event mean concentration
FDC	flow duration curve
GCHD	Galveston County Health District
GIS	geographic information system
GPS	global positioning system
HCFCD	Harris County Flood Control District
HCOEM	Harris County Office of Emergency Management
H-GAC	Houston-Galveston Area Council
LA	load allocation
LDC	load duration curve
mL	milliliter
MOS	margin of safety
MS4	municipal separate storm sewer system
NOAA	National Oceanic and Atmospheric Administration
NPDES	National Pollution Discharge Elimination System
NRCS	National Resources Conservation Service
OSSF	on-site sewage facility
RMSE	root mean square error
SSO	sanitary sewer overflow
SWQS	surface water quality standards
SWQMIS	Surface Water Quality Information System
TAC	Texas Administrative Code
TCEQ	Texas Commission on Environmental Quality
TCOON	Texas Coastal Ocean Observation Network
TMDL	Total Maximum Daily Loads

TPDES	Texas Pollution Discharge Elimination System
TSARP	Tropical Storm Allison Recovery Project
TWDB	Texas Water Development Board
USACE	U.S. Army Corps of Engineers
USDA	U.S. Department of Agriculture
USEPA	U.S. Environmental Protection Agency
USGS	U.S. Geological Survey
WLA	waste load allocation
WQM	water quality monitoring
WQS	water quality standard
WWTF	wastewater treatment facility

CHAPTER 1
INTRODUCTION

1.1 Watershed Description

Six new segments in the general Houston Metropolitan Area are considered impaired water bodies for contact recreation because they do not meet indicator bacteria (*Escherichia coli* [*E. coli*]) water quality standards. These segments are located in a number of watersheds in the San Jacinto River basin including, Brays Bayou Watershed, Hunting Bayou Watershed, Buffalo/Whiteoak Bayou Watershed, and the Sims Bayou Watershed. This TMDL report addresses the newly listed segments.

Subwatershed List

In 2008, total maximum daily loads (TMDLs) were developed for the twenty-seven impaired segments in the Houston Metropolitan Area. The 2008 project was subdivided into five subprojects: Greens Bayou Watershed, Halls Bayou Watershed, Brays Bayou Watershed, Sims Bayou Watershed, and Eastern Houston Watersheds. This report focuses on the following additional waterbodies that TCEQ placed in Category 5 [303(d) list] of the Draft 2010 Integrated Report for nonsupport of contact recreation use:

- Bintliff Ditch (1007T_01)
- Mimosa Ditch (1007U_01)
- Poor Farm Ditch (1007S_01)
- Unnamed Tributary of Hunting Bayou (1007V_01)
- Vogel Creek (1017C_01)
- Canal C-147 (1007A_01)

Figure 1-1 is a location map showing these Texas waterbodies and their contributing watersheds. The delineation of each subwatershed is derived from 2005 geographic information system (GIS) data files created for the Tropical Storm Allison Recovery Project (TSARP) provided by Harris County Flood Control District (HCFCD). Using the TSARP GIS file produces watershed delineations that are slightly different than the historic delineations based on TCEQ GIS files associated with classified segments (Segments 1007 and 1017). The importance of the watershed delineations based on the TSARP subwatershed delineations and their influence on the calculation method used for establishing TMDLs, will be discussed in more detail in Section 2.4 of this report. These waterbodies and their surrounding watersheds are hereinafter referred to as the Study Area.

The climate of the region is subtropical humid, with very hot and humid summers and mild winters (USACE 1985). The average maximum daytime temperature is 34 degrees Celsius (93 degrees Fahrenheit) while the temperature averages between 4 and 16 degrees Celsius (39 to 61 degrees Fahrenheit) during the winter. Summer rainfall is dominated by sub-tropical convection, winter rainfall by frontal storms, and fall and spring months by combinations of these two (Burian 2005).

Table 1-1, derived from the 2000 and 2010 U.S. Census, demonstrates that the counties in which these watersheds are located are very densely populated and shows the population growth per county (U.S. Census Bureau 2010).

Table 1-1 County Population and Density

County Name	2000 U.S. Census	2000 Population Density (per square mile)	2010 U.S. Census	2010 Population Density (per square mile)
Harris	3,400,578	1,967	4,092,459	2,367
Fort Bend	354,452	405	585,375	669

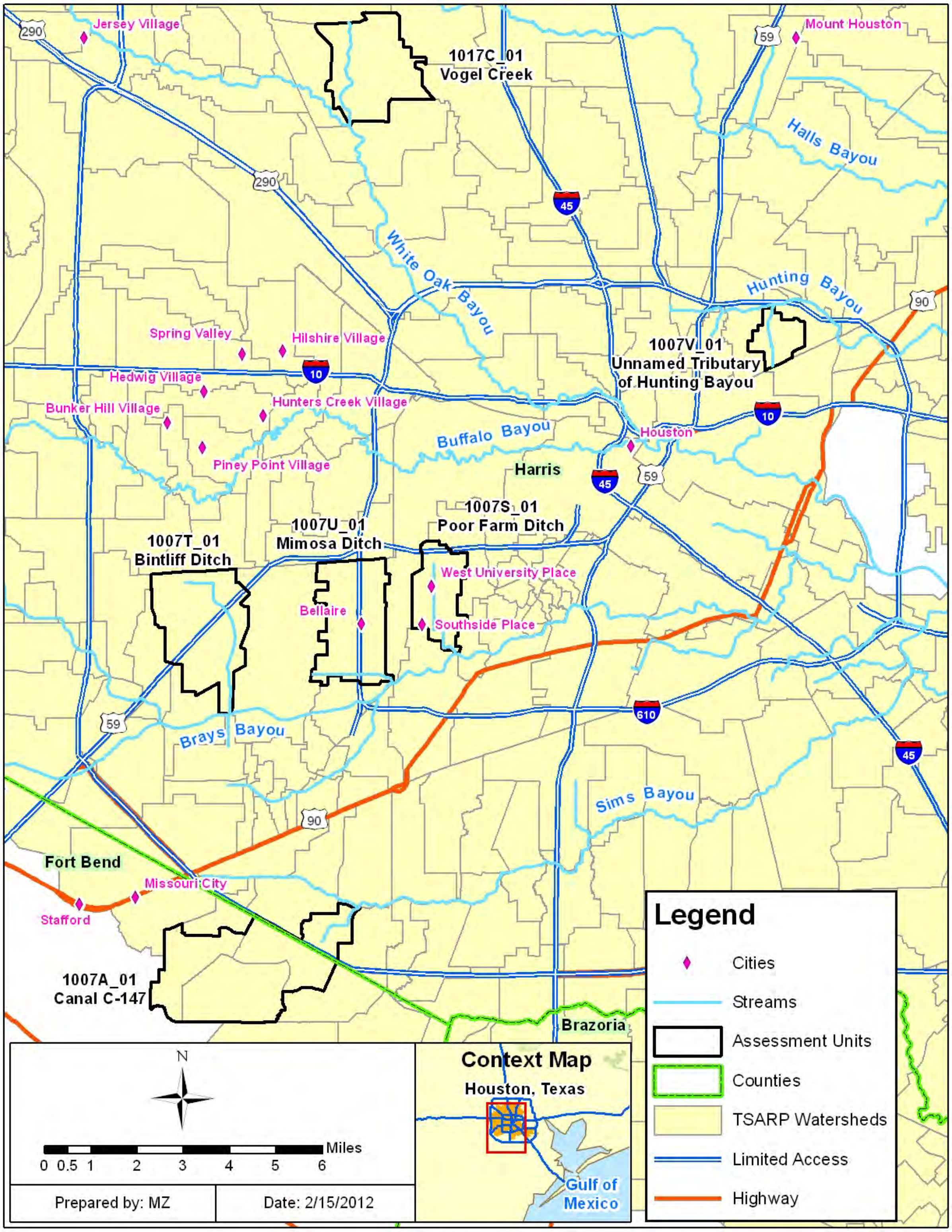

Figure 1-1 Location Map for Study Area

1.2 Summary of Existing Data

The following subsections summarize existing data relevant to soil, land use, and precipitation throughout the watershed as well as the chemical and physical characteristics of the waterbodies using ambient water quality and stream flow.

1.2.1 Soil

The geology of the Study Area comprises unconsolidated clay, clay shale, and poorly cemented sand that extend several miles in depth (TCEQ 2005). The soil has a low water-bearing capacity, high moisture content, low permeability, and a high shrink-swell potential. The State Soil Geographic Database (STATSGO) (National Resources Conservation Service [NRCS] 1994) information was used to characterize soil in the Study Area. As can be observed in Figure 1-2, the soil types that dominate the watershed are from the Edna, Lake Charles, and Clodine soil series, with a very small portion composed of Katy and Bernard soils. Table-1-2 lists the distribution and attributes of the three soil series found in the Study Area.

Table 1-2 Characteristics of Soil Types within the Study Area

NRCS Soil Type	Surface Texture	Soil Series Name	Hydro-logic Soil Group	Watershed	Percent of Watershed Area	Soil Drainage Class	Min Water Capacity (in/in)	Max Water Capacity (in/in)	Min Bulk Density (g/cm3)
TX048	Clay Loam	Bernard-Morey-Mocarey	D	Unnamed Tributary of Hunting Bayou (1007V_01)	46%	Somewhat Poorly Drained	0.15	0.2	1.2
TX100	Loam	Clodine-Addicks-Gessner	D	Unnamed Tributary of Hunting Bayou (1007V_01)	23%	Poorly Drained	0.15	0.2	1.35
				Vogel Creek (1017C_01)	82%				
TX163	Fine Sandy Loam	Edna-Bernard-Verland	D	Canal C-147 (1007A_01)	71%	Somewhat Poorly Drained	0.1	0.15	1.4
				Poor Farm Ditch (1007S_01)	65%				
				Bintliff Ditch (1007T_01)	96%				
				Mimosa Ditch (1007U_01)	48%				
TX248	Fine Sandy Loam	Katy-Aris-Clodine	D	Vogel Creek (1017C_01)	18%	Somewhat Poorly Drained	0.15	0.2	1.3
TX276	Clay	Lake Charles-Bernard-Edna	D	Canal C-147 (1007A_01)	29%	Somewhat Poorly Drained	0.15	0.2	1.2
				Poor Farm Ditch (1007S_01)	35%				
				Bintliff Ditch (1007T_01)	4%				
				Mimosa Ditch (1007U_01)	52%				
				Unnamed Tributary of Hunting Bayou (1007V_01)	31%				

All information derived from STATSGO data
Weighted Avg Water capacity is in units of (inches of water/inch of soil)

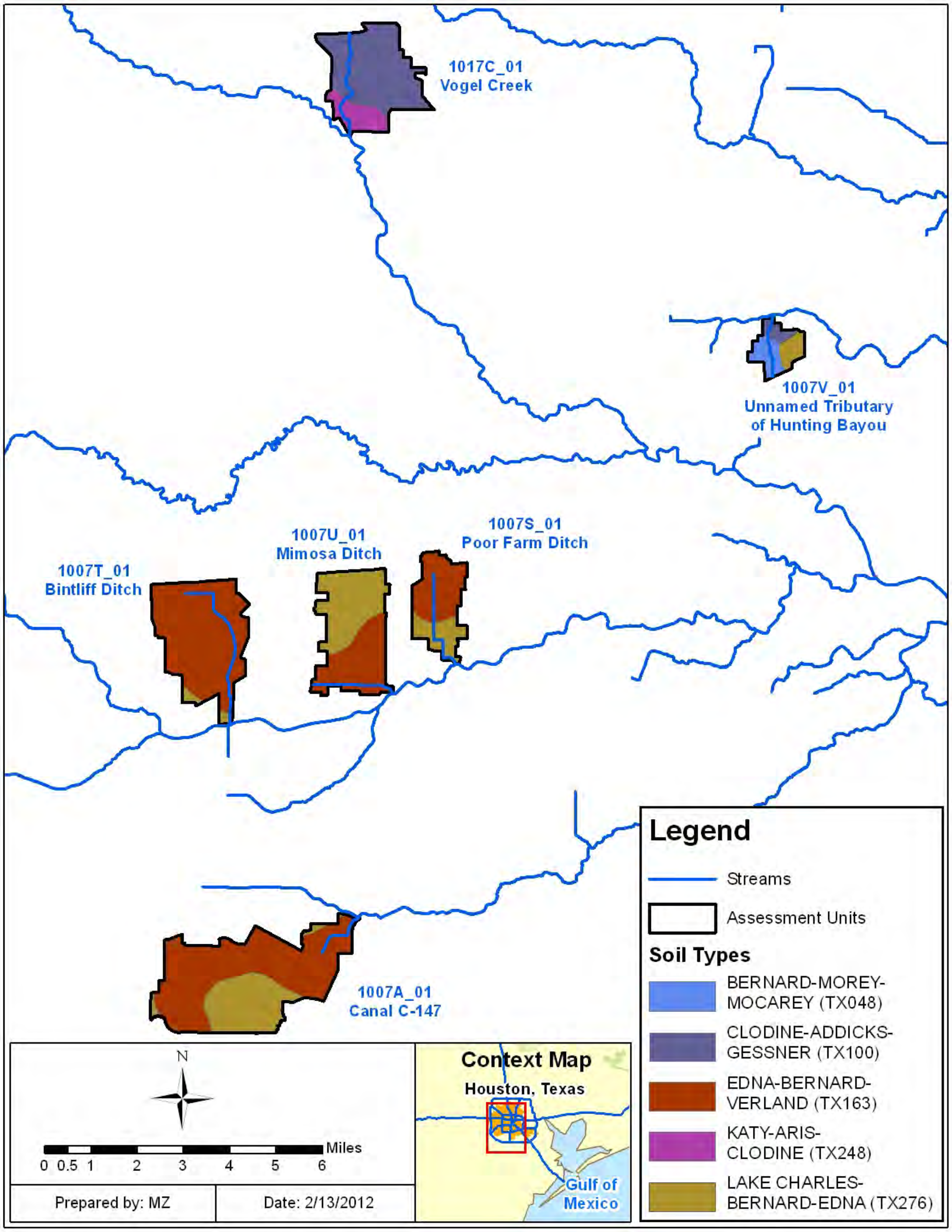

Figure 1-2 Study Area Soil Types

1.2.2 Land Use

Table 1-3 summarizes the acreages and the corresponding percentages of the land use categories for the each subwatershed in the Study Area. The land use/land cover data were retrieved from the National Oceanic and Atmospheric Administration's (NOAA) Coastal Services Center. The specific land use/land cover data files were derived from the Coastal Change Analysis Program (C-CAP), Texas 2005 Land Cover Data (NOAA 2007). The total acreage of each segment in Table 1-4 corresponds to the watershed delineation in Figure 1-3. The predominant land use category in this watershed is developed land (between 78% and 99%) followed by pasture/hay (between 0% and 11%) and woody land (between 0% and 8%). Open water and bare/transitional land account for less than 1.5 percent of the assessment units.

Table 1-3 Aggregated Land Use Summaries by Segment

Aggregated Landuse Category	Segment Name and ID					
	Bintliff Ditch	Mimosa Ditch	Poor Farm Ditch	Unnamed Tributary	Vogel Creek	Canal C-147
	1007T_01	1007U_01	1007S_01	1007V_01	1017C_01	1007A_01
Acres of Developed	2,904	2,361	1,336	632	2,150	3,611
Acres Cultivated Land	0	0	0	0	0	0.2
Acres Pasture/Hay	0	0	0	0	5.6	518
Acres Grassland/Herbaceous	0	0	0	0	19	161
Acres of Woody Land	3.1	14	0.7	7.1	203	237
Acres of Open Water	0.4	0.2	1.1	0	0	2.4
Acres of Wetland	0	0	0.2	0	9.1	58
Acres of Bare/Transitional	0.2	0	0	0	8.0	4.2
Watershed Area (acres)	**2,908**	**2,375**	**1,338**	**639**	**2,394**	**4,592**
Percent Developed	99.9%	99.4%	99.9%	98.9%	89.8%	78.6%
Percent Cultivated Land	0%	0%	0%	0%	0%	0.005%
Percent Pasture/Hay	0%	0%	0%	0%	0.2%	11%
Percent Grassland/Herbaceous	0%	0%	0%	0%	0.8%	3.5%
Percent Woody Land	0.11%	0.59%	0.05%	1.1%	8.5%	5.2%
Percent Open Water	0.02%	0.01%	0.08%	0%	0%	0.05%
Percent Wetland	0%	0%	0.02%	0%	0.38%	1.3%
Percent Bare/Transitional	0.08%	0%	0%	0%	0.33%	0.09%

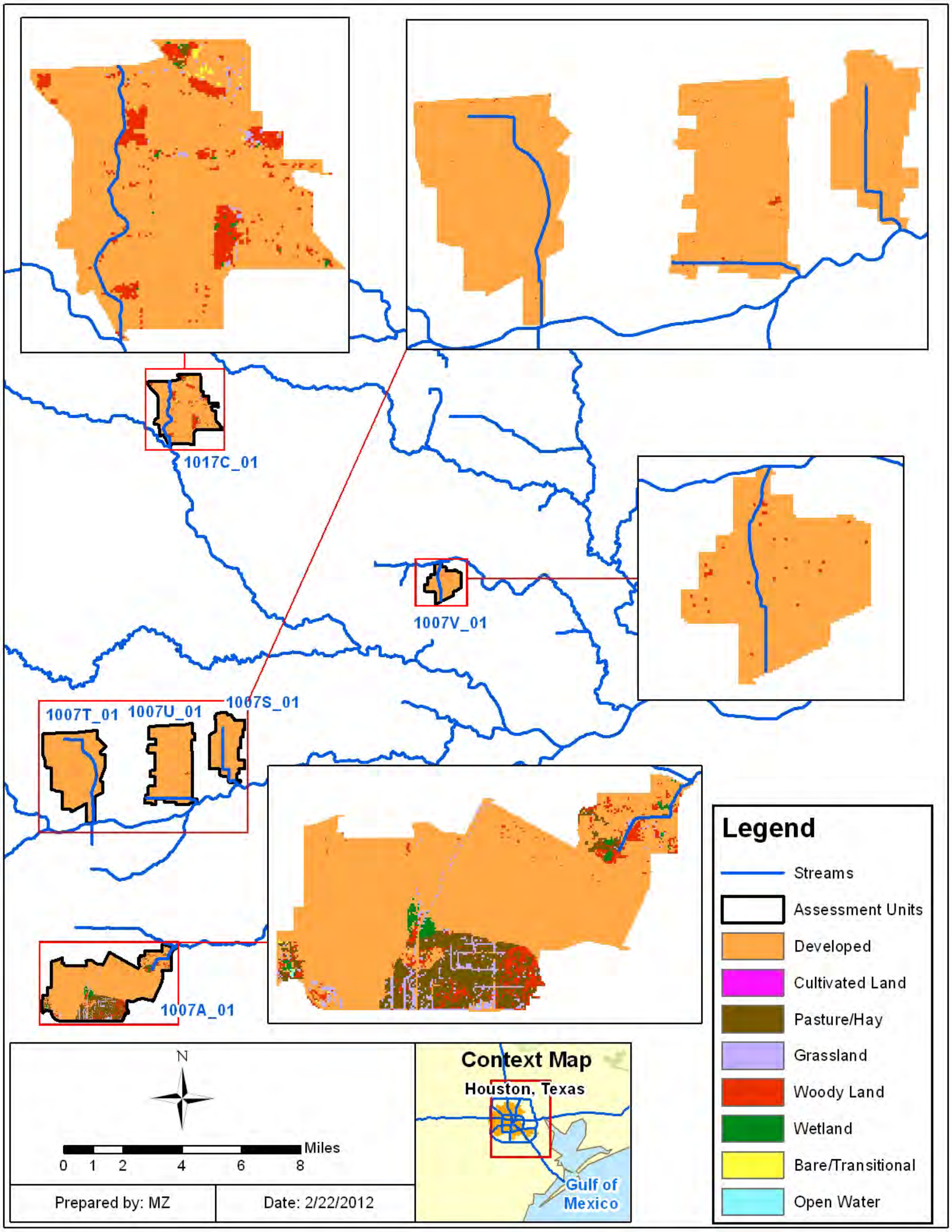

Figure 1-3 Land Use Map

1.2.3 Precipitation

There are several rain gauges located within the Houston Metropolitan Area (Figure 1-4). The gauges are maintained by the Harris County Office of Homeland Security and Emergency Management (HCOEM). Table 1-4 summarizes total annual rainfall for the gauges either within the subwatershed or closest to the subwatershed, for a 13-year period. The region has high levels of humidity and receives annual rainfall ranging between 15 and 80 inches per year (Table 1-4). Based on data for the period 1999 to 2011, the average precipitation for the selected gauges is around 46.4 inches per year. Figure 1-4 shows average annual rainfall across the Study Area. This grid was obtained by kriging data from 148 HCOEM rain gauges located across Harris, Fort Bend and Galveston counties for the time period of 1988 to 2007. Average values by subwatershed are summarized in Table 1-5. These average values were used to support the development of flow duration curves (Section 4).

Table 1-4 Annual Totals at Rainfall Gages in Study Area Watershed

Assessment Unit	1007T_01	1007U_01	1007S_01	1007V_01	1017C_01		1007A_01
Gauge number	**460***	**430***	**3380**	**840***	**585**	**595**	**380***
1999	37.1	NA	NA	39.09	NA	NA	35.9
2000	40.7	50.6	NA	44.21	NA	NA	42.3
2001	54.3	77.8	NA	58.5	NA	58.6	65.9
2002	49.8	50.7	NA	54.33	NA	58.6	43.2
2003	39.1	41.6	NA	48.27	46.57	45.96	42.1
2004	52.5	55	NA	76.1	64.17	63.47	42.1
2005	29.7	37.2	61.85	52.13	44.57	43.16	24.7
2006	34.2	39.3	18.58	68.07	56.97	60.12	48
2007	60.3	61.7	52.95	80.59	73.15	72.07	60.9
2008	40.79	43.94	59.45	33.43	49.21	53.57	46.06
2009	47.36	42.05	21.14	42.01	51.22	36.27	43.27
2010	52.82	46.64	46.64	43.22	41.88	42.97	45.26
2011	20.16	15.84	15.84	22.88	25.32	24.32	22.64
Average	**43.0**	**46.9**	**39.5**	**51.0**	**50.3**	**50.8**	**43.3**

**Indicates rain gauge not located within subwatershed*

Table 1-5 Average Annual Precipitation in the Study Area, 1988-2007 (in inches)

Segment Name	Segment ID	Average Annual (Inches)
Bintliff Ditch	1007T_01	46.71
Mimosa Ditch	1007U_01	48.62
Poor Farm Ditch	1007S_01	48.98
Unnamed Tributary	1007V_01	50.85
Vogel Creek	1017C_01	52.17
Canal C-147	1007A_01	46.39

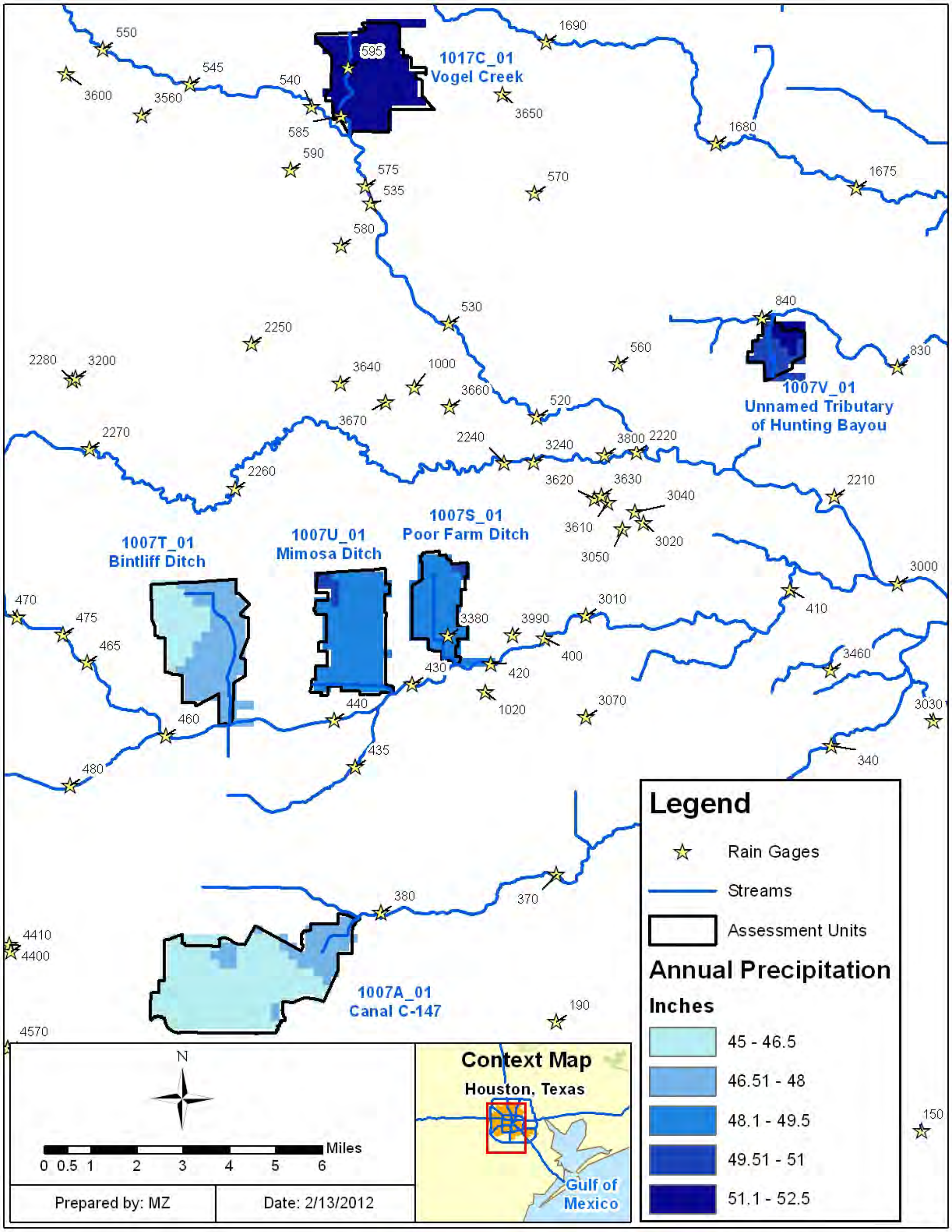

Figure 1-4 Precipitation Map

1.2.4 Ambient Water Quality

Considerable amounts of ambient water quality data are available to support water quality assessment and development of TMDLs for segments in the Study Area. Historical indicator bacteria data for the period 1999 to 2011 were obtained from the TCEQ SWQMIS database. Eighty-two percent of the data correspond to *E. coli* concentrations (439 samples), while 18 percent correspond to fecal coliform concentrations (99 samples).

Table 1-6 summarizes the historical ambient water quality data for indicator bacteria (1999-2011) for select TCEQ Water Quality Monitoring (WQM) stations in the Study Area. Figure 1-5 shows the locations of the WQM locations with indicator bacteria data. The complete ambient water quality data set for bacteria used to prepare Table 1-6 is provided in Appendix A. Table 1-6 includes the number of indicator bacteria samples, as well as the geometric mean of the concentrations for each indicator, and the number and percentage of single sample exceedances of the Texas SWQS. A more in-depth discussion of the analysis of this data set is provided in Subsections 2.3 and 2.4.

Table 1-6 Historical Water Quality Data for TCEQ Stations from 1999 to 2011

Segment	Station ID	Description	Geometric Mean (MPN/100ml)	Number of Samples	Number of Samples Exceeding Single Sample Criteria	% of Samples Exceeding
1007T_01	18690	EC	5206	56	49	88%
1007U_01	18691	EC	3613	56	53	95%
1007S_01	18692	EC	1368	57	42	74%
1007V_01	18689	EC	375	57	32	56%
1017C_01	11155	EC	386	69	28	41%
1007A_01	16656	FC	349	64	29	45%
		EC	356	98	41	42%
	15875	FC	1786	35	26	74%
		EC	698	46	31	67%

EC: E. coli, FC: Fecal Coliform
Geometric Mean Criteria: 126 MPN/100 ml for EC, 200 MPN/100 ml for FC.
Single Sample Criteria: 399 MPN/100 ml for EC, 400 MPN/100 ml for FC.

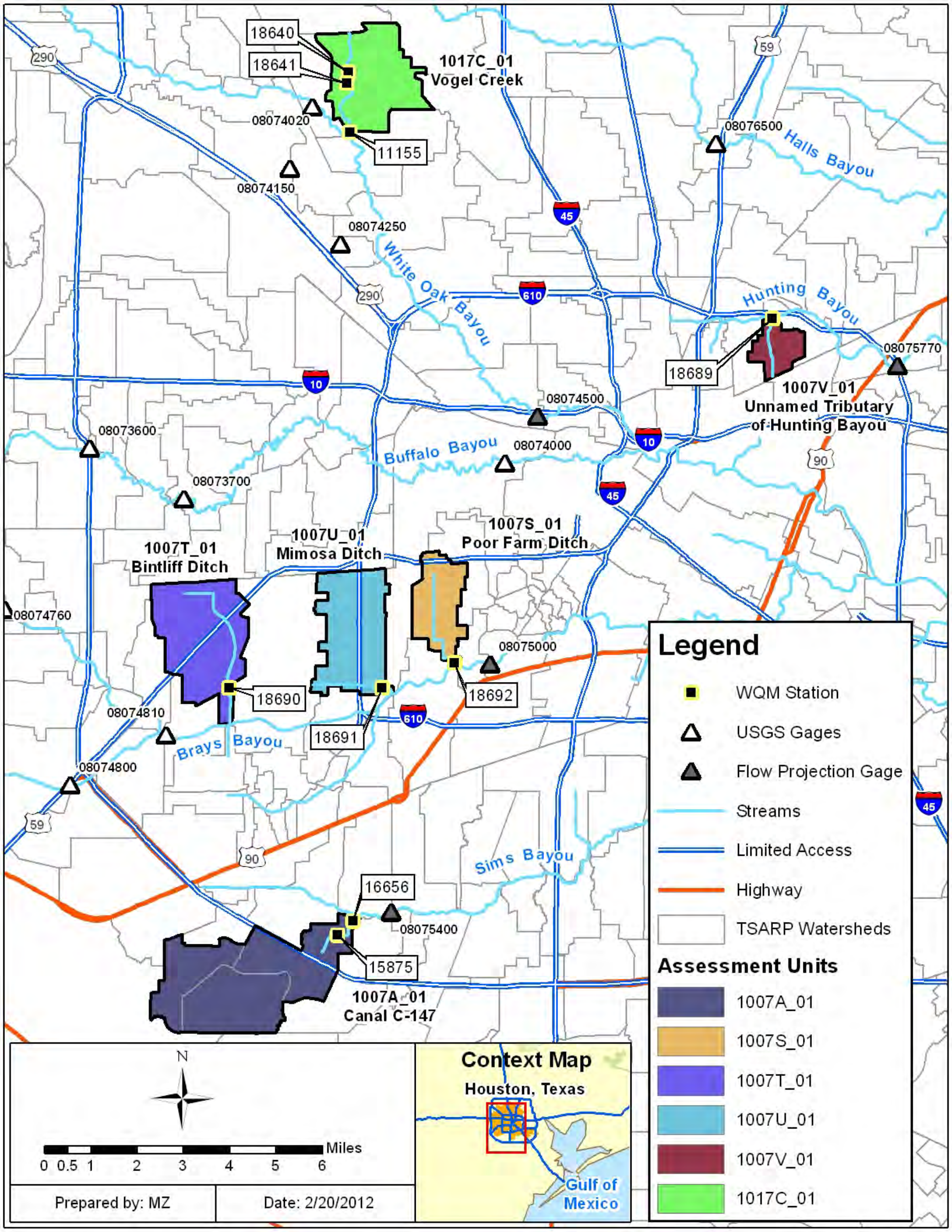

Figure 1-5 WQM Station Locations

1.2.5 Stream Flow Data

Stream flow data is key information when conducting water quality assessments such as TMDLs. There are no U.S. Geological Survey (USGS) operated flow gages located within the impaired subwatersheds.

Since there are no USGS gages within the subwatersheds, USGS gages located in the downstream receiving waterbody for each subwatershed were used to estimate flows. The period of record and type of data collected at the gages are listed in Table 1-7. The locations of these gage stations are shown on Figure 1-5. The historical flow data available from these stations are summarized as flow exceedance percentiles in Appendix B.

Table 1-7 USGS Gages used for Flow Projection

Gage Number	Name	Period of Record	Data Type
08074500	Whiteoak Bayou at Houston, TX	5/25/1936-Present	Discharge (cfs)
08075000	Brays Bayou at Houston, TX	5/25/1936-Present	Discharge (cfs)
08075770	Hunting Bayou at IH 610, Houston, TX	4/14/1964-Present	Discharge (cfs)
08075400	Sims Bayou at Hiram Clarke St, Houston, TX	8/18/1964-Present	Discharge (cfs)

No other historical flow data were available during water quality sample collection to assist in characterizing flows.

1.3 Seasonality

Seasonal differences in indicator bacteria concentrations were assessed by comparing historical bacteria concentrations collected in the warmer months versus those collected during the cooler months. The monthly average temperatures for Houston obtained from NOAA (Table 1-8) and the following criteria were used to divide the data sets into warmer (24 – 32°C) and cooler months (12 – 18°C). Based on these temperature ranges, November, December, January, and February were cooler months, and May, June, July, August, and September were warmer months.

Table 1-8 Average Monthly Temperatures for Houston Hobby AP, TX (1971-2000)

Month	Daily Max (°C)	Daily Min (°C)	Daily Mean (°C)	Classification
Jan	17.4	7.3	12.4	Cool
Feb	19.5	9	14.3	Cool
Mar	23.1	12.7	17.9	
Apr	26.3	15.9	21.1	
May	29.9	20.1	25	Warm
Jun	32.8	23.1	27.9	Warm
Jul	34.2	24.1	29.2	Warm
Aug	34.1	24.1	29.1	Warm
Sep	31.8	22	26.9	Warm
Oct	27.8	16.8	22.3	
Nov	22.5	11.9	17.2	Cool
Dec	18.6	8.2	13.4	Cool

Note: Temperature values from NOAA (degrees Fahrenheit) have been converted to degrees Celsius.
http://cdo.ncdc.noaa.gov/cgi-bin/climatenormals/climatenormals.pl

A t-test was conducted on log transformed data between the warmer months and cooler months for stations with 6 or more samples. Geometric means were also calculated for the warmer and cooler months. Table 1-9 shows seasonal variation for seven stations for *E.Coli* and two stations for fecal coliform.

Table 1-9 shows that 2 out of 2 stations (100%) exhibited higher fecal coliform geometric means for warmer months than for colder months, with 1 out of the 2 stations showing a statistically significant difference (*p*-value<0.05).

For *E. coli*, 4 out of 7 stations (57%) exhibited higher geometric means for warmer months than for colder months. However, none were found to be significantly different.

Table 1-9 Seasonal Differences for *E. coli* and Fecal Coliform Concentrations

<table>
<tr><th rowspan="2">Segment</th><th rowspan="2">Station ID</th><th rowspan="2">Indicator</th><th colspan="2">Warm Months</th><th colspan="2">Cold Months</th><th rowspan="2">p-value</th></tr>
<tr><th>n</th><th>Geomean</th><th>n</th><th>Geomean</th></tr>
<tr><td>1007T_01</td><td>18690</td><td>EC</td><td>20</td><td>9032</td><td>18</td><td>3389</td><td>0.164508</td></tr>
<tr><td>1007U_01</td><td>18691</td><td>EC</td><td>20</td><td>5691</td><td>19</td><td>4384</td><td>0.560683</td></tr>
<tr><td>1007S_01</td><td>18692</td><td></td><td>20</td><td>3549</td><td>19</td><td>751</td><td>0.058127</td></tr>
<tr><td>1007V_01</td><td>18689</td><td>EC</td><td>19</td><td>573</td><td>19</td><td>233</td><td>0.071776</td></tr>
<tr><td>1017C_01</td><td>11155</td><td>EC</td><td>24</td><td>285</td><td>23</td><td>659</td><td>0.057627</td></tr>
<tr><td rowspan="4">1007A_01</td><td rowspan="2">15875</td><td>EC</td><td>17</td><td>569</td><td>18</td><td>866</td><td>0.545346</td></tr>
<tr><td>FC</td><td>17</td><td>2796</td><td>8</td><td>2142</td><td>0.813791</td></tr>
<tr><td rowspan="2">16656</td><td>EC</td><td>36</td><td>402</td><td>34</td><td>411</td><td>0.940999</td></tr>
<tr><td>FC</td><td>29</td><td>623</td><td>19</td><td>129</td><td>0.002557</td></tr>
</table>

n = number of samples
Highlighted rows correspond to stations for which the warm and cold datasets are significantly different at a 95% confidence interval.
p-value is based on a t-test conducted at each station using single sample concentrations.
All concentrations are in counts/dL.

CHAPTER 2
PROBLEM IDENTIFICATION AND WATER QUALITY TARGET

2.1 Pollutant of Concern: Characteristics of Bacterial Indicators

The contact recreation use is assigned to almost every designated water body in the State of Texas, although full support of the contact recreation use is not a guarantee that the water is completely safe of disease-causing organisms. The evolution of the contact recreation criteria currently used by Texas began with criteria first published in 1968 based on general studies done on lakes in the Midwest and New York using fecal coliform bacteria as an indicator of the potential presence of fecal contamination (USEPA 1986). The USEPA-recommended criteria for recreational waters in 1976 included a geometric mean criterion: no more than 200 counts/dL based on five samples collected over a 30-day period; and an instantaneous criterion: no more than 10 percent of the individual grab samples could exceed 400 counts/dL (USEPA 1986). Shortly thereafter, these recommended criteria were adopted by the State of Texas in its SWQSs. These criteria, and the studies on which they were based, were heavily criticized by the USEPA in 1986 (USEPA 1986) following an extensive program of epidemiology testing. During that decade, USEPA studies found that fecal coliform was not a good predictor of the risk of disease and recommended new tests and criteria. The USEPA recommended new criteria for swimming areas, using *E. coli* as new fecal indicator organism, and incorporating the idea of varying criteria with the level of swimming use.

In Texas, two indicator bacteria are analyzed in freshwater samples collected to determine support of the contact recreation use: fecal coliform and *E. coli*. *E. coli* bacteria are measured to determine the relative risk of contact recreation. The presence of these bacteria indicates that associated pathogens from the fecal waste of warm-blooded species (human or animal) may be reaching a body of water. The standard associated with contact recreation use is designed to ensure that water is safe for swimming, wading by children or other water sports that involve direct contact with the water, especially with the possibility of ingesting it. High concentrations of certain bacteria in water indicate there may be an increased risk of becoming ill from recreational activities.

Texas water quality standards (WQS) for contact recreation allow exemptions for waterbodies where elevated bacteria concentrations frequently occur due to sources of pollution that cannot be reasonably controlled by the existing regulations, or where recreation is considered unsafe for other reasons, such as barge or ship traffic (*e.g.,* Houston Ship Channel), unrelated to water quality. This exemption and reclassification to less strict “noncontact recreation” standards has been applied to only a few waterbodies in Texas.

2.2 TCEQ Water Quality Standards for Contact Recreation

The TCEQ is responsible for administering provisions of the constitution and laws of the State of Texas to promote judicious use of and protection of the quality of waters in the state. Included in this responsibility is the continuous monitoring and assessment of water quality to evaluate compliance with SWQSs established within Texas Water Code, §26.023 and Title 30 Texas Administrative Code (TAC), §§307.1-307.10. Texas SWQS, 30 TAC 307.4, specify the designated uses and general criteria for all surface waters in the state.

This report focuses on six waterbodies within the Houston Metropolitan Area that are on the Texas 2010 Clean Water Act §303(d) list because they do not support contact recreation use. Table 2-1 summarizes the designated uses and the applicable bacteria indicators used to assess the contact recreation use of each waterbody addressed in this report. Table 2-1 also identifies the year each waterbody was placed on the Texas' Clean Water Act §303(d) List for nonsupport of contact recreation use, the stream length in miles, and other designated uses for each waterbody. The TMDLs in this report only address the contact recreation use. TMDLs are a necessary step in the process to restore contact recreation use for each waterbody.

Table 2-1 Synopsis of Texas Integrated Report for Waterbodies in the Study Area

Segment ID	Segment Name	Parameter	Designated Use*				Year Impaired	Stream Length (miles)
			CR	AL	GU	FC		
1007T_01	Bintliff Ditch	*E. coli*	NS	S	S	NA	2010	0.35
1007U_01	Mimosa Ditch	*E. coli*	NS	S	S	NA	2010	1.8
1007S_01	Poor Farm Ditch	*E. coli*	NS	S	S	NA	2010	2.3
1007V_01	Unnamed Tributary of Hunting Bayou	*E. coli*	NS	S	S	NA	2010	1.1
1017C_01	Vogel Creek	*E. coli*	NS	S	S	NA	2010	2
1007A_01	Canal C-147 Tributary of Sims Bayou Above Tidal	*E. coli*	NS	S	S	NA	2006	0.44

* *CR: Contact recreation; AL: Aquatic Life; GU: General Use; F: Fish Consumption; NS: Nonsupport; S = Support*

The excerpts below from Chapter 307, Texas SWQS (TCEQ 2010) stipulate how water quality data were assessed to determine support of contact recreation use as well as how the water quality targets are defined for each bacterial indicator. In addition to the specific requirements of §307.7 outlined below, the TMDLs for the Houston Metropolitan Area will also adhere to §307.5 of the SWQS which defines the antidegradation policy and procedures that apply to authorized wastewater discharges, TMDLs, waste load evaluations, and any other miscellaneous actions, such as those related to man-induced nonpoint sources of pollution, which may impact the water in the state (TCEQ 2010).

§307.7. Site-specific Uses and Criteria.

(a) Uses and numerical criteria are established on a site-specific basis in Appendices A, B, D, E, F, and G of §307.10 of this title (relating to Appendices A - G). Site-specific uses and numerical criteria may also be applied to unclassified waters in accordance with §307.4 of this title (relating to General Criteria) and §307.5(c) of this title (relating to Antidegradation). Site-specific criteria apply specifically to substances attributed to waste discharges or human activity. Site-specific criteria do not apply to those instances when surface waters exceed criteria due to natural phenomena. The application of site-specific uses and criteria is described in §307.8 of this title (relating to the Application of Standards) and §307.9 of this title (relating to the Determination of Standards Attainment).

(b) Appropriate uses and criteria for site-specific standards are defined as follows.

(1) Recreation. Recreational use consists of four categories--primary contact recreation, secondary contact recreation 1, secondary contact recreation 2, and noncontact recreation waters. Classified segments are designated for primary contact recreation unless sufficient site-specific information demonstrates that elevated concentrations of indicator bacteria frequently occur due to sources of pollution that cannot be reasonably controlled by existing regulations, wildlife sources of bacteria are unavoidably high and there is limited aquatic recreational potential, or primary or secondary contact recreation is considered unsafe for other reasons such as ship or barge traffic. In a classified segment where contact recreation is considered unsafe for reasons unrelated to water quality, a designated use of noncontact recreation may be assigned either noncontact recreation criteria or criteria normally associated with primary contact recreation. A designation of primary or secondary contact recreation is not a guarantee that the water so designated is completely free of disease-causing organisms. Indicator bacteria, although not generally pathogenic, are indicative of potential contamination by feces of warm blooded animals. Recreational criteria are based on these indicator bacteria rather than direct measurements of pathogens. Criteria are expressed as the number of bacteria per 100 milliliters (ml) of water (in terms of colony forming units, most probable number, or other applicable reporting measures). Even where the concentration of indicator bacteria is less than the criteria for primary or secondary contact recreation, there is still some risk of contracting waterborne diseases. Additional guidelines on minimum data requirements and procedures for evaluating standards attainment are specified in the TCEQ Guidance for Assessing and Reporting Surface Water Quality in Texas, as amended.

(A) Freshwater

(i) Primary contact recreation. The geometric mean criterion for E. coli is 126 per 100 ml. In addition, the single sample criterion for E. coli is 399 per 100 ml.

(ii) Secondary contact recreation 1. The geometric mean criterion for E. coli is 630 per 100 ml.

(iii) Secondary contact recreation 2. The geometric mean criterion for E. coli is 1,030 per 100 ml.

(iv) Noncontact recreation. The geometric mean criterion for E. coli is 2,060 per 100 ml.

(v) For high saline inland water bodies where Enterococci is the designated recreational indicator in Appendix A of §307.10 of this title, Enterococci is the applicable recreational indicator for instream bacteria sampling at all times for the classified water body and for the unclassified water bodies that are within the watershed of that classified segment, unless it is demonstrated that an unclassified water body is not high saline. E. coli is the applicable recreational indicator for instream bacteria sampling at all times for unclassified water bodies where conductivity values indicate that the water bodies are not high saline. For high saline inland waters with primary contact recreation, the geometric mean criterion for Enterococci is 33 per 100 ml and the single sample criterion is 78 per 100 ml. For high saline inland waters with secondary contact recreation 1, the geometric mean criterion for Enterococci is 165 per 100 ml. For high saline inland waters with secondary contact recreation 2, the geometric mean criterion for Enterococci is 270 per 100 ml. For high saline inland water bodies with noncontact recreation, the geometric mean criterion for Enterococci is 540 per 100 ml.

(B) Saltwater.

(i) Primary contact recreation. The geometric mean criterion for Enterococci is 35 per 100 ml. In addition, the single sample criterion for Enterococci is 104 per 100 ml.

(ii) Secondary contact recreation 1. A secondary contact recreation 1 use for tidal streams and rivers can be established on a site-specific basis in §307.10 of this title if justified by a use-attainability analysis and the water body is not a coastal recreation water as defined in the Beaches Environmental Assessment and Coastal Health Act of 2000 (BEACH Act). The geometric mean criterion for Enterococci is 175 per 100 ml.

(iii) Noncontact recreation. A noncontact recreation use for tidal streams and rivers can be established on a site-specific basis in §307.10 of this title if justified by a use-attainability analysis and the water body is not a coastal recreation water as defined in the BEACH Act. The geometric mean criterion for Enterococci is 350 per 100 ml.

(C) Fecal coliform bacteria. Fecal coliform bacteria can be used as an alternative instream indicator of recreational suitability in high saline inland water bodies where Enterococci is the designated recreational indicator in Appendix A of §307.10 of this title for two years after the adoption of this title to allow time to collect sufficient data for Enterococci. Fecal coliform criteria for high saline inland water bodies are as follows:

(i) Primary contact recreation. The geometric mean criterion for fecal coliform is 200 per 100 ml. In addition, the single sample criterion for fecal coliform is 400 per 100 ml.

(ii) Secondary contact recreation 1 and 2. The geometric mean criterion for fecal coliform is 1,000 per 100 ml.

(iii) Noncontact recreation. The geometric mean criterion for fecal coliform is 2,000 per 100 ml.

(D) Swimming advisory programs. For areas where local jurisdictions or private property owners voluntarily provide public notice or closure based on water quality, the use of any single-sample or short-term indicators of recreational suitability are selected at the discretion of the local managers of aquatic recreation. Guidance for single-sample bacterial indicators is available in the United States Environmental Protection Agency (EPA) document

entitled Ambient Water Quality Criteria for Bacteria - 1986. Other short-term indicators to assess water quality suitability for recreation - such as measures of streamflow, turbidity, or rainfall - may also be appropriate.

As stipulated in 2010 *Guidance for Assessing and Reporting Surface Water Quality in Texas* (TCEQ 2010), utilization of the geometric mean to determine compliance for any of the bacterial indicators depends on the collection of at least 10 samples over the most recent 10-year period.

2010 Guidance for Assessing and Reporting Surface Water Quality in Texas (TCEQ 2010)*:*

- *All assessment methods based on the average will require 10 samples for listing and delisting, although in rare instances the assessor will make the use attainment decision with fewer samples and indicate this by reporting a data set qualifier of JQ (based on judgment of the assessor).*
- *The 2010 assessment period of record for the last seven years is December 1, 2001 through November 30, 2008. Samples from these seven years are evaluated when available, if necessary; the most recent samples collected in the preceding three years (December 1, 1998 through November 30, 2000) can also be included to meet the requirements for minimum sample number.*

2.3 Problem Identification

Pursuant to §303(d) of the federal Clean Water Act, states must establish TMDLs for pollutants contributing to violations of WQSs. Table 2-2 identifies the waterbodies requiring TMDLs identified in Category 5 of the 2010 Texas Water Quality Inventory and §303(d) List (TCEQ 2010). Between 1996 and 2010 as the TCEQ WQSs and water quality assessment method were modified and additional water quality data were collected throughout the Houston Metropolitan Area, new assessment areas were added to the §303(d) List. Table 2-2 lists the TCEQ WQM stations from which ambient water quality data were summarized to support the decision to place these waterbodies on the TCEQ 303(d) List. The waterbodies requiring the TMDLs were first listed in 2010. The locations of these WQM stations are displayed in Figure 2-1.

A number of changes have occurred in the past 10 years that warrant refinements in how indicator bacteria data are used to support water quality assessments and TMDL development in Texas. Some key factors that influence which indicator bacteria to use for water quality assessment and TMDL development and the period of record to use include:

- changes in land use and locations of Texas Pollution Discharge Elimination System (TPDES)-permitted facilities;
- changing the indicator bacteria in the 2000 TCEQ surface water quality standards (SWQS) from fecal coliform to *E. coli* for fresh water;
- refinements in the TCEQ surface water quality monitoring procedures; and
- changes in the TCEQ guidance, *Assessing and Reporting Surface Water Quality in Texas.*

As a result of these evolving factors in the water quality management arena associated with the protection and maintenance of contact recreation use, the historical data set used to support the TMDLs in this report have been narrowed, wherever possible, to utilize only *E. coli* from 2001 through 2011.

Table 2-2 Water Quality Monitoring Stations Used for 303(d) Listing Decision

Segment ID	Segment Name	Description	Monitoring Station IDs	Year
1007T_01	Bintliff Ditch	From the Brays Bayou confluence to 0.57 km (0.35 mi) upstream of the Fondren Road bridge crossing	18690	2010
1007U_01	Mimosa Ditch	From the Brays Bayou confluence upstream 2.9 km (1.8 mi) to the Chimney Rock bridge crossing	18691	2010
1007S_01	Poor Farm Ditch	From the Brays Bayou confluence upstream 3.6 km (2.3 mi) to the Bissonnet Road bridge crossing	18692	2010
1007V_01	Unnamed Tributary of Hunting Bayou	From the Hunting Bayou confluence to 1.7 km (1.1 mi) upstream of the confluence (0.3 km west of Collingsworth Street	18689	2010
1017C_01	Vogel Creek	From the White Oak Bayou confluence to a point 3.2 km (2.0 mi) upstream	11155	2010
1007A_01	Canal C-147 Tributary of Sims Bayou Above Tidal	From the Sims Bayou confluence upstream to a point 0.71 km (0.44 mi) east of Beltway 8	15875, 16656	2006

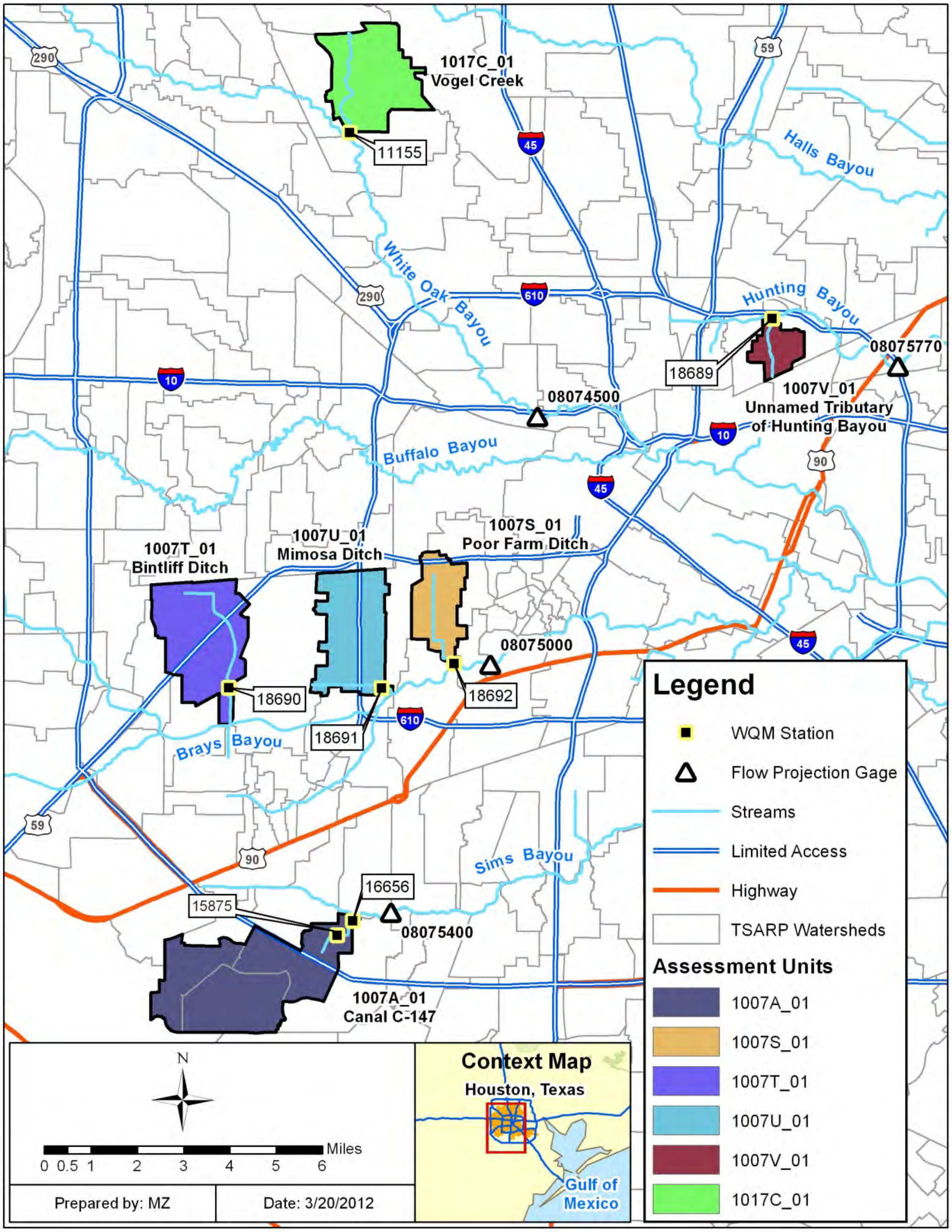

Figure 2-1 TCEQ WQM Stations in the Study Area

Table 2-3 summarizes the ambient water quality data for the TCEQ WQM stations on each impaired waterbody. From these data results, key inferences can be made regarding the temporal and spatial extent of the contact recreation use impairment.

Table 2-3 Water Quality Data for TCEQ Stations from 1999 to 2011

Segment	Station ID	Description	Geometric Mean (MPN/100ml)	Number of Samples	Number of Samples Exceeding Single Sample Criteria	% of Samples Exceeding
1007T_01	18690	EC	5206	56	49	88%
1007U_01	18691	EC	3613	56	53	95%
1007S_01	18692	EC	1368	57	42	74%
1007V_01	18689	EC	375	57	32	56%
1017C_01	11155	EC	386	69	28	41%
1007A_01	16656	FC	349	64	29	45%
		EC	356	98	41	42%
	15875	FC	1786	35	26	74%
		EC	698	46	31	67%

EC: E. coli, FC: Fecal Coliform
Geometric Mean Criteria: 126 MPN/100 ml for EC, 200 MPN/100 ml for FC.
Single Sample Criteria: 399 MPN/100 ml for EC, 400 MPN/100 ml for FC.
Highlight indicates downstream WQM station selected for TMDL development and indicator bacteria selected as water quality target.

Bintliff Ditch (Segment 1007T_01): Both the single sample and geometric mean criteria for *E. coli* were exceeded at the only location within this subwatershed.

Mimosa Ditch (Segment 1007U_01): Both the single sample and geometric mean criteria for *E. coli* were exceeded at the only location within this subwatershed.

Poor Farm Ditch (Segment 1007S_01): Both the single sample and geometric mean criteria for *E. coli* were exceeded at the only location within this subwatershed.

Unnamed Tributary of Hunting Bayou (Segment 1007V_01): Both the single sample and geometric mean criteria for *E. coli* were exceeded at the only location within this subwatershed.

Vogel Creek (Segment 1017C_01): Both the single sample and geometric mean criteria for *E. coli* were exceeded at the only location within this subwatershed.

Canal C-147 (Segment 1007A_01): Both the single sample and geometric mean criteria for *E. coli* and fecal coliform were exceeded at both WQM station locations within this subwatershed.

2.4 Water Quality Targets for Contact Recreation

The Code of Federal Regulations (40 CFR §130.7(c)(1)) states that, "TMDLs shall be established at levels necessary to attain and maintain the applicable narrative and numerical water quality standards." The Texas SWQSs (TCEQ 2010) provide numeric and narrative criteria to evaluate attainment of designated uses. The basis for water quality targets for all TMDLs developed in this report will be the numeric criteria for bacterial indicators from the 2010 Texas SWQSs as described in Subsection 2.2 above. *E. coli* is the preferred indicator bacteria for assessing contact recreation use in freshwater but fecal coliform bacteria may also be used since it was the preferred indicator in the past.

Several studies performed by the USEPA show a stronger link between the concentrations of *E. coli* and the concentrations of fecal pathogens than the previous standard, fecal coliform. The USEPA studies found that in freshwater streams, *E. coli* concentrations were the strongest predictor of illness following contact recreation. The TCEQ adopted the limit of 399 per dL for single samples of *E. coli* and a geometric mean limit of 126 per dL for waterbodies that have been designated for contact recreation use.

The water quality target for the TMDLs in the Study Area is to maintain concentrations below the geometric mean criterion of 126 counts per dL for *E. coli*. Maintaining the geometric mean criterion for each indicator bacteria is expected to be protective of the single sample criterion also and therefore will ultimately result in the attainment of the contact recreation use. TMDLs will be based on a percent reduction goal required to meet the geometric mean criterion.

The water quality target for each waterbody will incorporate an explicit 5 percent margin of safety (MOS). For example, if *E. coli* is utilized to establish the TMDL, then the water quality target would be 379 counts/dL, 5 percent lower than the single sample water quality criterion (399 counts/dL) and the geometric mean water quality target would be 120 counts/dL, 5 percent lower than the criterion value (126 counts/dL).

CHAPTER 3
POLLUTANT SOURCE ASSESSMENT

To support TMDL development, a pollutant source assessment attempts to characterize known and suspected sources of pollutant loading to impaired waterbodies. Pollutant sources within a watershed are categorized and quantified to the extent that information is available. Fecal bacteria such as *E. coli* originate in the intestines of warm-blooded species (human and animal), and sources of bacteria may be point (permitted) or nonpoint (non-permitted) in nature.

Point sources are permitted through the National Pollution Discharge Elimination System (NPDES) program. Some storm water runoff may be permitted through NPDES as municipal separate storm sewer systems (MS4). Other non-permitted sources of storm water runoff that typically cannot be identified as entering a waterbody through a discrete conveyance at a single location are often referred to as nonpoint sources. For example, non-permitted sources include land activities that contribute bacteria to surface water as a result of rainfall runoff or on-site sewage system facilities. For the TMDLs in this report, all sources of pollutant loading not regulated by a NPDES-permit are considered nonpoint sources. The following discussion describes what is known regarding permitted and non-permitted sources of bacteria in the impaired watersheds.

3.1 Point Sources: NPDES/TPDES-Permitted Sources

Under 40 CFR, §122.2, a point source is described as a discernable, confined, and discrete conveyance from which pollutants are or may be discharged to surface waters. Under the Texas Water Code, TCEQ has adopted rules and procedures to issue permits to control the quantity and quality of discharges into or adjacent to waters of the state through the TPDES program. NPDES/TPDES-permitted facilities classified as point sources that may contribute bacteria loading to surface waters include:

- TPDES municipal wastewater treatment facilities (WWTF);
- TPDES industrial WWTF;
- TPDES municipal no-discharge WWTF;
- TPDES regulated storm water (municipal separate storm sewer systems); and
- TPDES Concentrated Animal Feeding Operation (CAFO).

Continuous point source discharges such as WWTFs, could result in discharge of elevated concentrations of fecal bacteria if the disinfection unit is not properly maintained, is of poor design, or if flow rates exceed the disinfection capacity. Some industrial WWTF may contain fecal bacteria in their effluent. While no-discharge facilities do not discharge wastewater directly to a waterbody, it is possible that collection systems associated with these types of facilities may be a source of bacteria loading to surface waters. Permitted storm water runoff from TPDES regulated discharge areas, called municipal separate storm sewer systems, can also contain high fecal bacteria concentrations. CAFOs are recognized by USEPA as significant sources of pollution, and may have the potential to cause serious impacts to water quality if not properly managed.

Four watersheds in the Study Area, including Mimosa Ditch (1007U_01), Poor Farm Ditch (1007S_01), Vogel Creek (1017C_01) and Canal C-147 (1007A_01) have NPDES/TPDES-permitted sources. A significant portion of the Study Area is regulated under the TPDES storm water discharge permit jointly held by Harris County, HCFCD, City of Houston, and Texas Department of Transportation. There are no NPDES-permitted CAFOs within the Study Area.

3.1.1 Permitted Sources: Continuous Point Source Discharges

There are six TPDES-permitted facilities that continuously discharge wastewater to surface waters addressed in these TMDLs as shown in Figure 3-1. Table 3-1 lists the TPDES-permitted facilities for which wasteload allocations will be developed under this TMDL study. There are no WWTFs located in Bintliff Ditch (1007T_01) or Unnamed Tributary of Hunting Bayou (1007V_01) watersheds.

Not all TPDES-permitted facilities that discharge treated wastewater are required to monitor for fecal bacteria. In addition, while current instream water quality criteria are based on *E. coli* and Enterococci bacteria, permit limits are based on levels of fecal coliform, another measure of fecal bacteria of which *E. coli* is often the major constituent. Table 3-2 summarizes self-reporting flow data available for the six existing facilities in the Study Area (See Appendix D for all self-reported flow data). No DMR data for fecal coliform were available for the TPDES WWTFs.

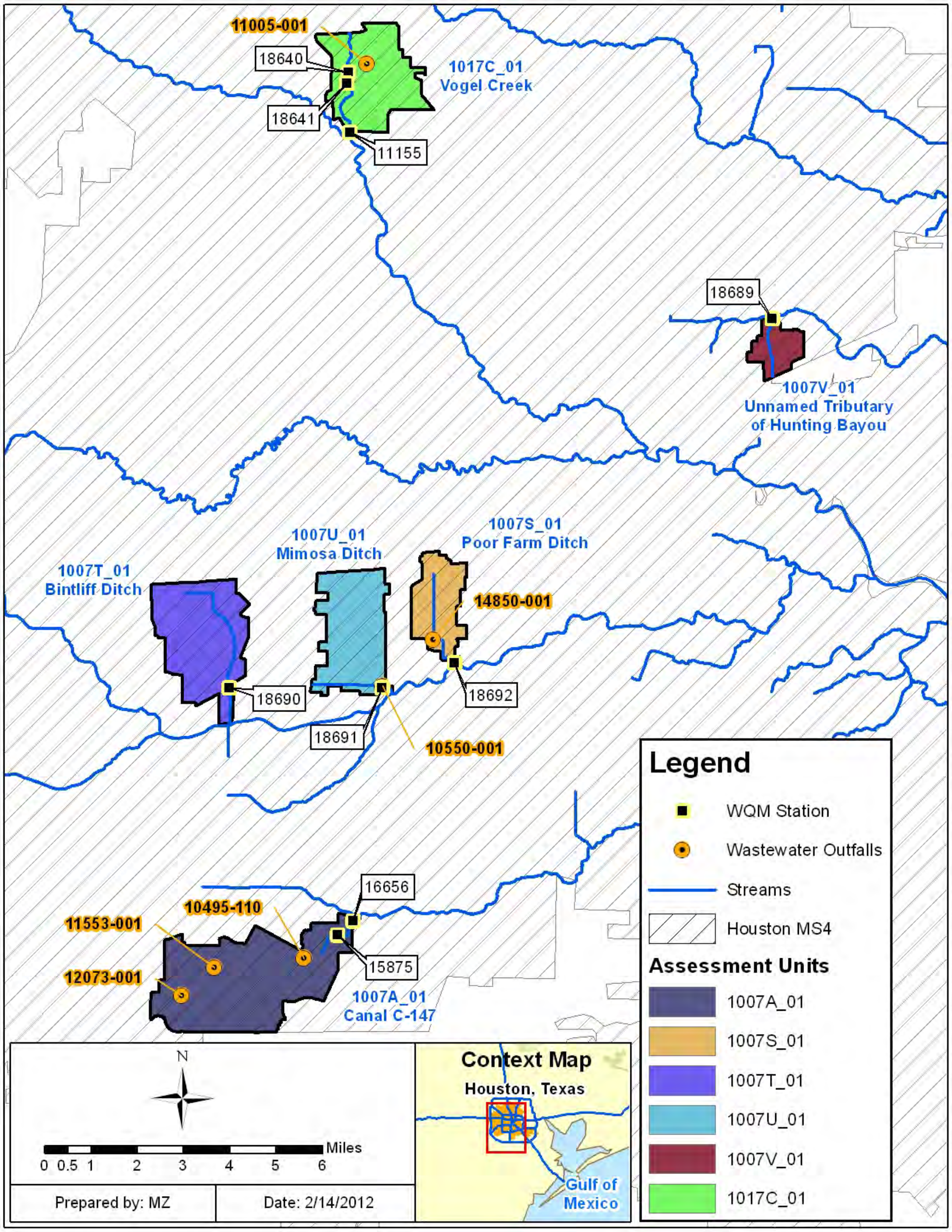

Figure 3-1 TPDES-Permitted Facilities in the Study Area

Table 3-1 TPDES-Permitted Facilities in the Study Area

Segment	Receiving Water	TPDES Number	NPDES NUMBER	Facility Name	Facility Type	DTYPE	County	Permitted Flow (MGD)	Average Monthly Flow (MGD)
1007U_01	Mimosa Ditch	10550-001	TX0020613	City of Bellaire-WWTP	Sewerage Systems	W	Harris	4.5	1.48
1007S_01	Poor Farm Ditch	14850-001	TX0026972	City of Southside Place	Sewerage Systems	D	Harris	0.3	0.21
1017C_01	Vogel Creek	11005-001	TX0020095	Champ's Water Company,W. Montgomery Subdivision-WWTP	Sewerage Systems	D	Harris	0.28	0.13
1007A_01	Canal C-147	11553-001	TX0053643	Blue Ridge West Mud-WWTP	Sewerage Systems	W	Fort Bend	1.3	0.83
		10495-110	TX0026433	City of Houston(Greenridge)	Sewerage Systems	W	Harris	7.05	2.66
		12073-001	TX0078891	Fort Bend County MUD No.26	Sewerage Systems	D	Fort Bend	0.8	0.32

Source: TCEQ Wastewater Outfall Shapefile, June 2011
MGD - Millions of Gallons per Day; TYPE: D = Domestic < 1 MGD; W=Domestic >= 1 MGD; N/A: Not available, facility is under construction

Table 3-2 DMR Data for Permitted Wastewater Discharges (December 1997-September 2009)

TPDES Number	NPDES Number	Facility Name	Segment	Stream Name	Dates Monitored		# of Records	Average Monthly Flow (MGD)	Permitted Flow (MGD)
					Start	End			
10550-001	TX0020613	City of Bellaire-WWTP	1007U_01	Mimosa Ditch	1/31/1998	3/31/2009	134	1.48	4.5
14850-001	TX0026972	City of Southside Place	1007S_01	Poor Farm Ditch	1/31/1998	04/31/2009	135	0.21	0.3
11005-001	TX0020095	Champ's Water Company,W. Montgomery Subdivision-WWTP	1017C_01	Vogel Creek	12/31/1997	04/31/2009	130	0.13	0.28
11553-001	TX0053643	Blue Ridge West Mud-WWTP			1/31/1998	5/31/2009	137	0.83	1.3
10495-110	TX0026433	City of Houston(Greenridge)			1/31/1998	04/31/2009	134	2.66	7.05
12073-001	TX0078891	Fort Bend County MUD No.26	1007A_01	Canal C-147	1/31/1998	04/31/2009	133	0.32	0.8

Source: EPA, PCS monitoring data search January 2012; Notes: FC = Fecal Coliform, NA = Not Applicable, MGD = Millions of Gallons per Day, counts = Colony Forming Unit

3.1.2 Permitted Sources: NPDES No-Discharge Facilities and Sanitary Sewer Overflows

There are no No-Discharge Facilities located within the Study Area.

Sanitary sewer overflows (SSO) are permit violations that must be addressed by the responsible TPDES permittee. SSOs most often result from blockages in the sewer collection pipes caused by tree roots, grease and other debris. The TCEQ maintains a database of SSO data collected from wastewater operators in the Study Area. TCEQ Region 12-Houston provided two database queries for SSO data – one is collected by the City of Houston and the other is compiled from the remainder of the wastewater dischargers in the Study Area (Rice 2005). These data are included in Table 3-3. As can be seen from Table 3-3, Bintliff Ditch (1007T_01) had the largest volume of sanitary sewer overflows reported. The SSOs were caused by a collapsed line. The locations and magnitudes of the reported SSOs are displayed in Figure 3-2. The WWTF service area boundaries are also shown in Figure 3-2.

Table 3-3 Sanitary Sewer Overflow (SSO) Summary

Facility Name	NPDES Permit No.	Facility ID	# of Occur-rences	Date Range		Amount (Gallons)			Segment
				From	To	Min	Max	Avg	
City of Houston - Green Ridge	TX0026433	10495-110	19	03/01/01	05/03/03	41	10775	1342	1007A_01
City of Houston - Almeda Sims	TX0034924	10495-003	3	09/24/01	04/19/02	209	2374	957	
City of Houston - Almeda Sims	TX0034924	10495-003	4	08/23/02	04/01/03	53	7166	1852	1007S_01
City of Houston - Southwest	TX0062995	10495-037	2	06/16/01	03/31/03	1640	11225	6433	
City of Houston - Southwest	TX0062995	10495-037	18	02/25/01	07/23/03	76	10448	1725	1007T_01
City of Houston - Keegans Bayou	TX0098191	10495-119	10	07/27/01	07/30/03	70	15000	3562	
City of Houston - Southwest	TX0062995	10495-037	1	03/09/01	03/09/01	3060	3060	3060	1007U_01
City of Houston - 69th Street	TX0096172	10495-090	13	04/12/01	07/14/03	53	4654	1558	1007V_01
City of Houston - North West Plant	TX0063011	10495-076	18	03/13/01	10/16/03	40	18514	2545	1017C_01

3.1.3 Permitted Sources: TPDES Regulated Storm Water

In 1990, the USEPA developed rules establishing Phase I of the NPDES Storm Water Program, designed to prevent harmful nonpoint sources of pollutants from being washed by storm water runoff into municipal separate storm sewer systems and then discharged into local waterbodies (USEPA 2005). Phase I of the program required medium and large permitted dischargers (those generally serving populations of 100,000 or greater) to implement a storm water management program as a means to control polluted discharges. Approved storm water management programs for medium and large permitted discharges are required to address a variety of water quality-related issues, including roadway runoff management, municipal-owned operations, and hazardous waste treatment.

Phase II of the rule extends coverage of the NPDES Storm Water program to certain small MS4s. Small MS4s are defined as any MS4 that is not a medium or large MS4 covered by Phase I of the NPDES Storm Water Program. Phase II requires operators of regulated small MS4s to obtain NPDES permits and develop a storm water management program. Programs are designed to reduce discharges of pollutants to the "maximum extent practicable," protect water quality, and satisfy appropriate water quality requirements of the CWA. Small MS4 storm water programs must address the following minimum control measures:

- Public Education and Outreach;
- Public Participation/Involvement;
- Illicit Discharge Detection and Elimination;

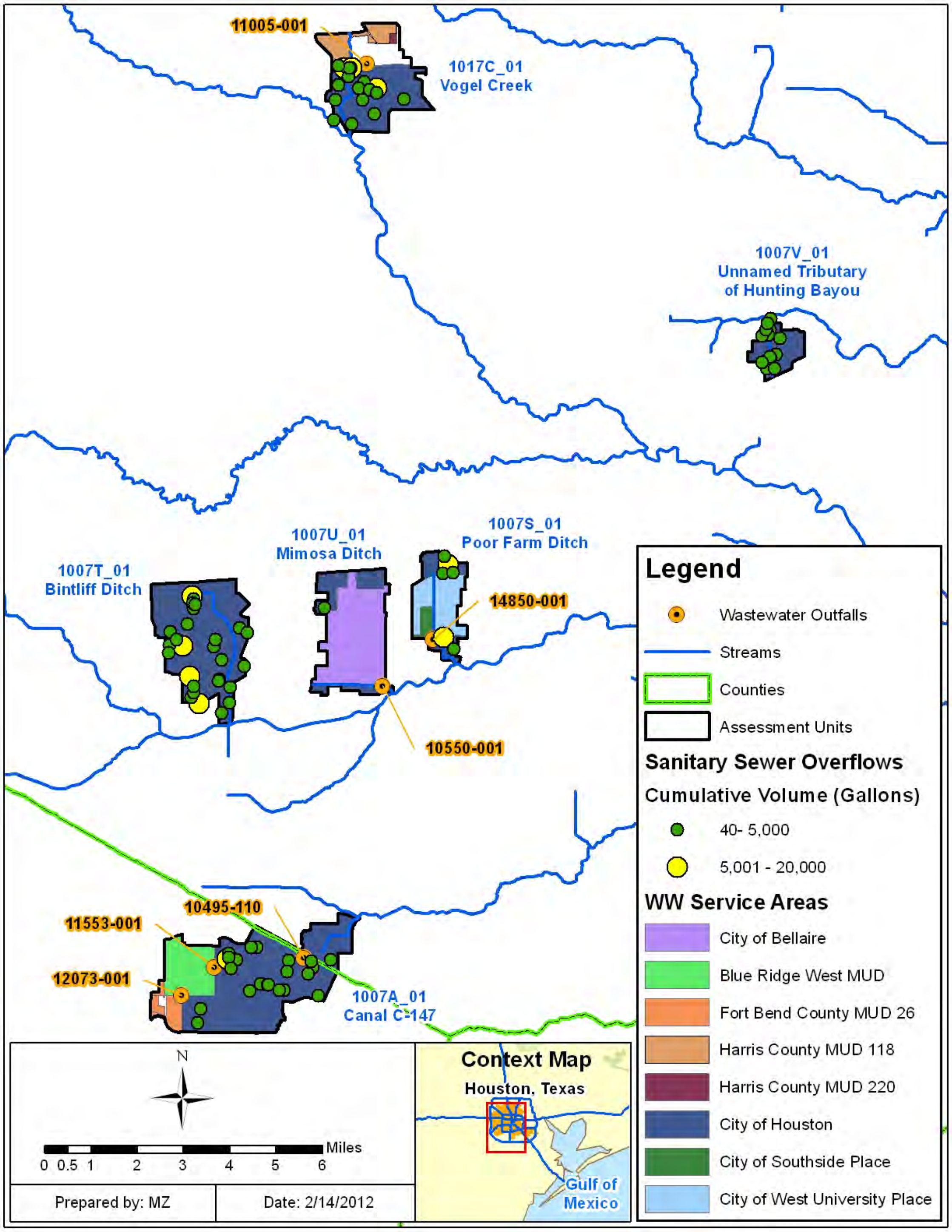

Figure 3-2 Sanitary Sewer Overflow Locations

- Construction Site Runoff Control;
- Post- Construction Runoff Control; and
- Pollution Prevention/Good Housekeeping.

When evaluating pollutant loads originating from storm water runoff, a critical distinction must be made between storm water originating from an area under an NPDES/TPDES regulated discharge permit and storm water originating from areas not under an NPDES/TPDES regulated discharge permit. To characterize pollutant loads from storm water runoff, it is necessary to segregate storm water into two categories: 1) permitted storm water, which is storm water originating from an NPDES/TPDES-permitted Phase 1 or Phase 2 urbanized area; and 2) non-permitted storm water, which is storm water originating from any area outside an NPDES/TPDES-permitted Phase 1 or Phase 2 urbanized area. Each subwatershed in the Study Area is covered under the City of Houston/Harris County MS4 permit (TPDES Permit No. WQ0004685000). The jurisdictional boundary of the Houston MS4 permit is derived from *Urbanized Area Map Results for Texas* which is based on the 2000 U.S. Census and can be found at the USEPA website http://cfpub.epa.gov/npdes/stormwater/urbanmapresult.cfm?state=TX. Figure 3-1 displays the portion of the watershed that contributes bacteria loads to the receiving waters from areas of permitted and non-permitted storm water.

Under the City of Houston/Harris County permitted discharge permit, Harris County, HCFCD, City of Houston, and Texas Department of Transportation are designated as co-permittees. These agencies do not have any monitoring points located on water bodies that drain into the Study Area (Martin 2005). Therefore, there are no monitoring data available to characterize bacteria concentrations or loads from regulated storm water discharged to receiving waters in the Study Area. Table 3-4 lists the percentage of area within each watershed covered under the Houston MS4 permit.

Table 3-4 Percentage of Permitted Storm Water in each Watershed

Segment	Receiving Stream	TPDES Number	Total Area (acres)	Area under MS4 Permit (Acres)	Percent of Subwatershed under MS4 Jurisdiction
1007T_01	Bintliff Ditch	WQ0004685000	2,904	2,904	100%
1007U_01	Mimosa Ditch	WQ0004685000	2,376	2,376	100%
1007S_01	Poor Farm Ditch	WQ0004685000	1,333	1,333	100%
1007V_01	Unnamed Tributary of Hunting Bayou	WQ0004685000	640	640	100%
1017C_01	Vogel Creek	WQ0004685000	2,400	2,400	100%
1007A_01	Canal C-147	WQ0004685000	4,591	4,591	100%

3.1.4 Concentrated Animal Feeding Operations

There are no CAFOs located within the Study Area.

3.2 Non-permitted Sources: Storm Water, On-site Sewage Facilities, and Direct Deposition

Non-permitted sources (nonpoint sources) include those sources that cannot be identified as entering the waterbody at a specific location. Bacteria originate from rural, suburban, and urban areas. The following section describes possible major nonpermitted sources contributing fecal coliform loading within the Study Area.

Nonpoint sources of bacteria can emanate from wildlife, various agricultural activities, and domesticated animals, land application fields, urban runoff, failing on-site sewage facilities (OSSF), and domestic pets. Bacteria associated with urban runoff can emanate from humans, wildlife, livestock, and domestic pets. Based on the ability of warm-blooded animals to harbor and shed human pathogens, the current USEPA policy establishes the position that it is inappropriate to conclude that livestock and wildlife sources present no risk to human health from waterborne pathogens. Consequently, states and authorized tribes should not use broad exemptions from the bacteriological criteria for waters designated for primary contact recreation based on the presumption that high levels of bacteria resulting from non-human fecal contamination present no risk to human health (USEPA 2002). Water quality data collected from streams draining urban communities often show existing concentrations of fecal coliform bacteria at levels greater than a state’s instantaneous standards. A study under USEPA’s National Urban Runoff Project indicated that the average fecal coliform concentration from 14 watersheds in different areas within the United States was approximately 15,000 /dL in storm water runoff (USEPA 1983). Non-permitted storm water can be a significant source of fecal bacteria.

3.2.1 Wildlife and Unmanaged Animal Contributions

Fecal coliform bacteria are common inhabitants of the intestines of all warm-blooded animals, including wildlife such as mammals and birds. In developing bacteria TMDLs, it is important to identify the potential for bacteria contributions from wildlife by watershed. Wildlife is naturally attracted to riparian corridors of streams and rivers. With direct access to the stream channel, the direct deposition of wildlife waste can be a concentrated source of bacteria loading to a waterbody. Fecal coliform bacteria from wildlife is also deposited onto land surfaces, where it may be washed into nearby streams by rainfall runoff. Typical of coastal watersheds, there is a significant population of avian species that frequent the watershed and the riparian corridors, in particular. However, currently there are insufficient data available to estimate populations and spatial distribution of wildlife and avian species by watershed. Consequently, it is difficult to assess the magnitude of bacteria contributions from wildlife species as a general category.

3.2.2 Non-Permitted Agricultural Activities and Domesticated Animals

There are a number of non-permitted agricultural activities that can also be sources of fecal bacteria loading. Given the fact that the Study Areas are highly urbanized, livestock and other domesticated animals are not found in these subwatersheds and therefore are not considered as a contributor of bacteria loads.

3.2.3 Failing On-site Sewage Facilities

On-site sewage facilities (OSSFs) can be a source of bacteria loading to streams and rivers. Bacteria loading from failing OSSFs can be transported to streams in a variety of ways, including runoff from surface ponding or through groundwater. Fecal coliform-contaminated groundwater can also be discharged to creeks through springs and seeps.

Over time, most OSSFs operating at full capacity will fail. OSSF failures are proportional to the adequacy of a state's minimum design criteria (Hall 2002). The 1995 American Housing Survey conducted by the U.S. Census Bureau estimates that, nationwide, 10 percent of occupied homes with OSSFs experience malfunctions during the year (U.S. Census Bureau 1995). A statewide study conducted by Reed, Stowe & Yanke, LLC (2001) reported that approximately 12 percent of the OSSFs in Harris County, which is part of Region 4, were chronically malfunctioning. Most studies estimate that the minimum lot size necessary to ensure against contamination is roughly one-half to one acre (Hall 2002). Some studies, however, found that lot sizes in this range or even larger could still cause contamination of ground or surface water (University of Florida 1987). It is estimated that areas with more than 40 OSSFs per square mile (6.25 septic systems per 100 acres) can be considered to have potential contamination problems (Canter and Knox 1985).

Only permitted OSSF systems are recorded by authorized county or city agents; therefore, it is difficult to estimate the exact number of OSSFs in use in the Study Area. Table 3-5 lists the OSSF totals based on the 1990 U.S. Census and the number of OSSF permits obtained by authorized county or city agents between 1992 -2010. Permits are obtained to install or replace systems. However, some permits are obtained when an older failing system needs repair (H-GAC 2005). It is assumed that there are more OSSFs in each city or county listed in Table 3-5 which were installed prior to 1992. Because the a portion of Canal C-147 (1007A_01) covers only portions of two of the counties listed in Table 3-5, specific steps were taken to estimate the proportion of OSSFs that exist within the six subwatersheds in the Study Area.

Table 3-5 Numbers of Permits Issued by Authorized County or City Agent

Year	Fort Bend	Harris
1990 Census Totals	9,721	44,120
1992	113	243
1993	252	651
1994	343	881
1995	347	1,035
1996	304	1,327
1997	343	1,393
1998	504	1,301
1999	594	1,606
2000	544	1,422
2001	444	1,388
2002	495	1,397
2003	538	1,424
2004	501	1,174
2005	550	1,080
2006	555	1,039
2007	458	989
2008	448	788
2009	366	721
2010	328	645
Total	**17,748**	**64,624**

Note: Data obtained from TCEQ On-Site Activity Reporting System
NA: Not Available

To estimate the potential magnitude of fecal bacteria loading from OSSFs, the number of OSSFs was estimated for each watershed. The estimate of OSSFs was derived by using data from the 1990 U.S. Census (U.S. Census Bureau 2000) and a GIS shapefile obtained from HGAC showing all areas where wastewater service currently exists. Figure 3-3 displays unsewered areas that did not fall under the wastewater service areas. OSSFs were calculated using spatial GIS queries for areas not covered by wastewater service areas. OSSFs were assigned proportionally based on the percentage of the area falling outside a wastewater service area within each watershed. Finally, the OSSFs for each unsewered area were then totaled by TMDL watershed. This approach gives an estimate of OSSFs in the watershed. Table 3-6 shows the estimated number of OSSFs calculated using this GIS method.

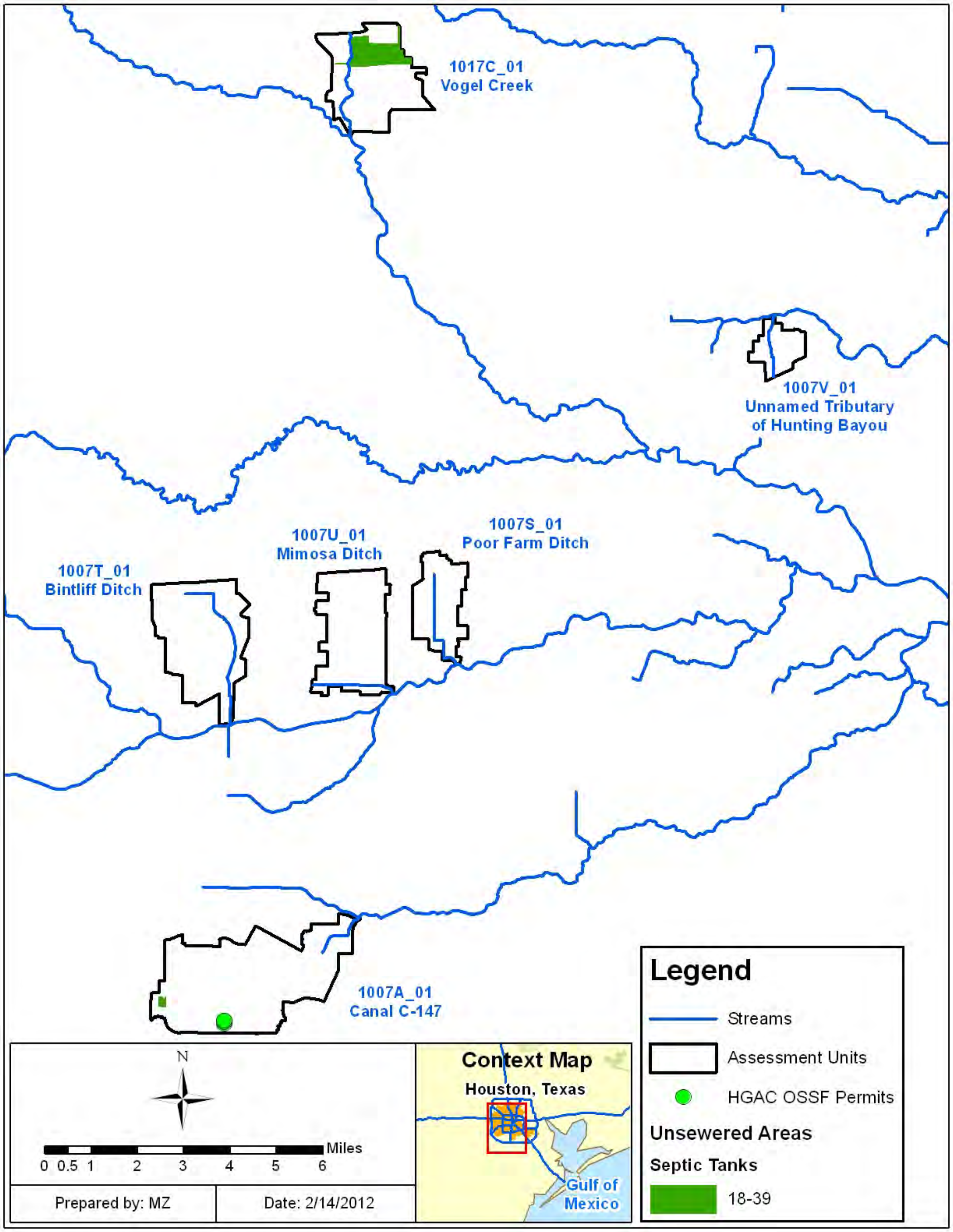

Figure 3-3 Unsewered Areas and Subdivisions with OSSF

HGAC provided additional OSSF data for select portions of the Study Area. There are four existing structures in Canal C-147 (1007A_01) subwatershed with low failure occurrences, as shown in Table 3-6. Figure 3-3 points out the subwatersheds that have been identified as having OSSFs.

For the purpose of estimating fecal coliform loading in watersheds, the OSSF failure rate of 12 percent from the Reed, Stowe & Yanke, LLC (2001) report for Texas Region 4 was used. Using this 12 percent failure rate, calculations were made to characterize fecal coliform loads in each watershed.

Fecal coliform loads were estimated using the following equation (USEPA 2001):

$$\#\frac{counts}{day} = \left(\#\,Failing\_systems\right) \times \left(\frac{10^{6}\,counts}{100\,ml}\right) \times \left(\frac{70\,gal}{person\,day}\right) \times \left(\#\frac{person}{household}\right) \times \left(3785.2\frac{ml}{gal}\right)$$

The average of number of people per household was calculated to be 2.78 for counties in the Study Area (U.S. Census Bureau 2000). Approximately 70 gallons of wastewater were estimated to be produced on average per person per day (Metcalf and Eddy 1991). The fecal coliform concentration in septic tank effluent was estimated to be 10^6 per dL of effluent based on reported concentrations from a number of published reports (Metcalf and Eddy 1991; Canter and Knox 1985; Cogger and Carlile 1984). Using this information, the estimated load from failing septic systems within the watersheds was summarized below in Table 3-6. Based on this data, it was determined that the estimated fecal coliform loading from OSSFs in the Study Area were found to be negligible.

Table 3-6 Estimated Number of OSSFs per Subwatershed and Fecal Coliform Load

Segment	Stream Name	OSSF Estimate using 1990 Census method	OSSF data from HGAC	# of Failing OSSFs	Estimated Loads from OSSFs (x 10^9 counts/day)
1007T_01	Bintliff Ditch	0	0	0.00	0
1007U_01	Mimosa Ditch	0	0	0.00	0
1007S_01	Poor Farm Ditch	0	0	0.00	0
1007V_01	Unnamed Tributary of Hunting Bayou	0	0	0.00	0
1017C_01	Vogel Creek	39	0	4.72	35
1007A_01	Canal C-147	18	4	2.62	19

3.2.4 Domestic Pets

Fecal matter from dogs and cats is transported to streams by runoff from urban and suburban areas and can be a potential source of bacteria loading. On average nationally, there are 0.58 dogs per household and 0.66 cats per household (American Veterinary Medical Association 2007). Using the U.S. Census data at the block level (U.S. Census Bureau 2010), dog and cat populations can be estimated for each watershed. Table 3-7 summarizes the estimated number of dogs and cats for the watersheds of the Study Area.

Table 3-7 Estimated Numbers of Pets

Segment	Stream Name	Dogs	Cats
1007T_01	Bintliff Ditch	8,444	9,526
1007U_01	Mimosa Ditch	4,611	5,202
1007S_01	Poor Farm Ditch	4,201	4,739
1007V_01	Unnamed Tributary of Hunting Bayou	903	1,018
1017C_01	Vogel Creek	3,796	4,282
1007A_01	Canal C-147	5,551	6,263

Table 3-8 provides an estimate of the fecal coliform load from pets. These estimates are based on estimated fecal coliform production rates of 5.4×10^8 per day for cats and 3.3×10^9 per day for dogs (Schueler 2000). Only a small portion of these loads is expected to reach waterbodies, through wash-off of land surfaces and conveyance in runoff.

Table 3-8 Estimated Fecal Coliform Daily Production by Pets (x 10^9)

Segment	Stream Name	Dogs	Cats	Total (cfu/day)
1007T_01	Bintliff Ditch	27,865	5,144	33,009
1007U_01	Mimosa Ditch	15,217	2,809	18,026
1007S_01	Poor Farm Ditch	13,863	2,559	16,422
1007V_01	Unnamed Tributary of Hunting Bayou	2,979	550	3,529
1017C_01	Vogel Creek	12,526	2,312	14,839
1007A_01	Canal C-147	18,320	3,382	21,702

3.2.5 Bacteria Re-growth and Die-off

Bacteria are living organisms that grow and die. Certain enteric bacteria can regrow in organic materials if appropriate conditions prevail (*e.g.,* warm temperature). It is shown in the general literature that fecal organisms can regrow from improperly treated effluent during their transport in pipe networks, and they can regrow in organic rich materials such as compost and sludges. While the die-off of indicator bacteria has been demonstrated in natural water systems due to the presence of sunlight and predators, the potential for their regrowth is less well understood. Both processes (regrowth and die-off) are in-stream processes and are not considered in the bacteria source loading estimates of each water body.

CHAPTER 4
TECHNICAL APPROACH AND METHODS

The objective of a TMDL is to estimate allowable pollutant loads and to allocate these loads to the known pollutant sources in the watershed so appropriate control measures can be implemented and the standard for contact recreation achieved. A TMDL is expressed as the sum of three elements as described in the following mathematical equation:

$$TMDL = \Sigma\ WLA + \Sigma\ LA + MOS$$

The wasteload allocation (WLA) is the portion of the TMDL allocated to existing and future permitted (point) sources. The load allocation (LA) is the portion of the TMDL allocated to non-permitted (nonpoint) sources, including natural background sources. The MOS is intended to ensure that standard for contact recreation will be met. Thus, the allowable pollutant load that can be allocated to point and nonpoint sources can then be defined as the TMDL minus the MOS.

40 CFR, §130.2(1), states that TMDLs can be expressed in terms of mass per time, toxicity, or other appropriate measures. For *E. coli* bacteria, TMDLs are expressed as numbers per day, where possible, or as a percent reduction goal, and represent the maximum one day load the stream can assimilate while still attaining the standard for contact recreation. For the six impaired subwatersheds addressed within the Study Area, allowable pollutant loads and percent reduction goals to achieve WQ standards for contact recreation are established using the load duration curve (LDC) method as described in this section.

4.1 Using Load Duration Curves to Develop TMDLs

The TMDL calculations included in this report are derived from LDCs. LDCs facilitate rapid development of TMDLs, and as a TMDL development tool, are effective at identifying whether impairments are associated with point or nonpoint sources. The technical approach for using LDCs for TMDL development includes the four following steps described in Subsections 4.2 through 4.4 below:

- preparing flow duration curves (FDC) for gaged and ungaged WQM stations;
- estimating existing bacteria loading in the receiving water using ambient water quality data;
- using LDCs to identify the critical condition that will dictate loading reductions necessary to attain the contact recreation standard; and
- interpreting LDCs to derive TMDL elements – WLA, LA, MOS, and percent reduction goal.

Historically, in developing WLAs for pollutants from point sources, it was customary to designate a critical low flow condition (*e.g.*, 7Q2) at which the maximum permissible loading was calculated. As water quality management efforts expanded in scope to quantitatively address nonpoint sources of pollution and types of pollutants, it became clear that this single critical low flow condition was inadequate to ensure adequate water quality across a range of flow conditions. Use of the LDC obviates the need to determine a design storm or selected flow recurrence interval with which to characterize the appropriate flow level for the assessment of critical conditions. For waterbodies impacted by both point and nonpoint sources, the “nonpoint source critical condition” would typically occur during high flows, when rainfall runoff would contribute the bulk of the pollutant load, while the “point source critical condition” would typically occur during low flows, when WWTF effluents would dominate the base flow of the impaired water.

LDCs display the maximum allowable load over the complete range of flow conditions by a line using the calculation of flow multiplied by the water quality criterion. Using LDCs, a TMDL can be expressed as a continuous function of flow, equal to the line, or as a discrete value derived from a specific flow condition.

4.2 Development of Flow Duration Curves

Flow duration curves serve as the foundation of LDCs and are graphical representations of the flow characteristics of a stream at a given site. FDCs utilize the historical hydrologic record from stream gages to forecast future recurrence frequencies. While many WQM stations throughout Texas do not have long term flow data, there are various methods that can be used to estimate flow frequencies at ungaged stations or gaged stations missing flow data. The most basic method to estimate flows at an ungaged site involves 1) identifying an upstream or downstream flow gage; 2) calculating the contributing drainage areas of the ungaged sites and the flow gage; and 3) calculating daily flows at the ungaged site by using the flow from an acceptable nearby gaged site multiplied by the drainage area ratio. In developing the FDC presented in this report, a more complex approach was used that also considers watershed differences in rainfall, land use, WWTF discharges, and the hydrologic properties of soil that govern runoff and retention. More than one upstream flow gage may also be considered. A more detailed explanation of the methods for estimating flow at ungaged WQM stations is provided in Appendix D.

Flow duration curves are a type of cumulative distribution function. The flow duration curve represents the fraction of flow observations that exceed a given flow at the site of interest. The observed flow values are first ranked from highest to lowest then, for each observation, the percentage of observations exceeding that flow is calculated. The flow value is read from the y-axis, which is typically on a logarithmic scale since the high flows would otherwise overwhelm the low flows. The flow exceedance frequency is read from the x-axis, which is numbered from 0 to 100 percent, and may or may not be logarithmic. The lowest measured flow occurs at an exceedance frequency of 100 percent indicating that flow has equaled or exceeded this value 100 percent of the time, while the highest measured flow is found at an exceedance frequency of 0 percent. The median flow occurs at a flow exceedance frequency of 50 percent.

While the number of observations required to develop a flow duration curve is not rigorously specified, a flow duration curve is usually based on more than 5-years of observations, and encompasses inter-annual and seasonal variation. Ideally, the drought of record and flood of record are included in the observations. For this purpose, the long-term flow gaging stations operated by the USGS are utilized. As previously mentioned in Section 1.2.2, there are no long-term flow data from within the Study Area. Therefore, flows needed to be estimated for each segment.

A typical semi-log flow duration curve exhibits a sigmoidal shape, bending upward near a flow exceedance frequency value of 0 percent and downward at a frequency near 100 percent, often with a relatively constant slope in between. For sites that on occasion exhibit no flow, the curve will intersect the abscissa at a frequency less than 100 percent. As the number of observations at a site increases, the line of the FDC tends to appear smoother. However, at extreme low and high flow values, flow duration curves may exhibit a "stair step" effect due to the USGS flow data rounding conventions near the limits of quantitation.

FDCs can be subdivided into hydrologic condition classes to facilitate the diagnostic and analytical uses of flow and LDCs. The hydrologic classification scheme utilized in this application is described as follows:

Table 4-1 Hydrologic Classification Scheme

Flow Exceedance Percentile	Hydrologic Condition Class
0-20	Highest flows
20-80	Mid-range flows
80-100	Lowest flows

Figures 4-1 to 4-6 present the FDCs developed for the downstream WQM stations used for calculating the TMDLs of the 303(d) listed streams using the flow projection method outlined above and further described in Appendix D. The flow exceedance percentiles for these segments are presented in tabular form in Appendix E.

Figure 4-1 represents the FDC for Bintliff Ditch, segment 1007T_01 at WQM station 18690. No WWTF discharges occur in Bintliff Ditch. Flows were estimated using USGS gage station 8075000 (Brays Bayou at Houston, TX).

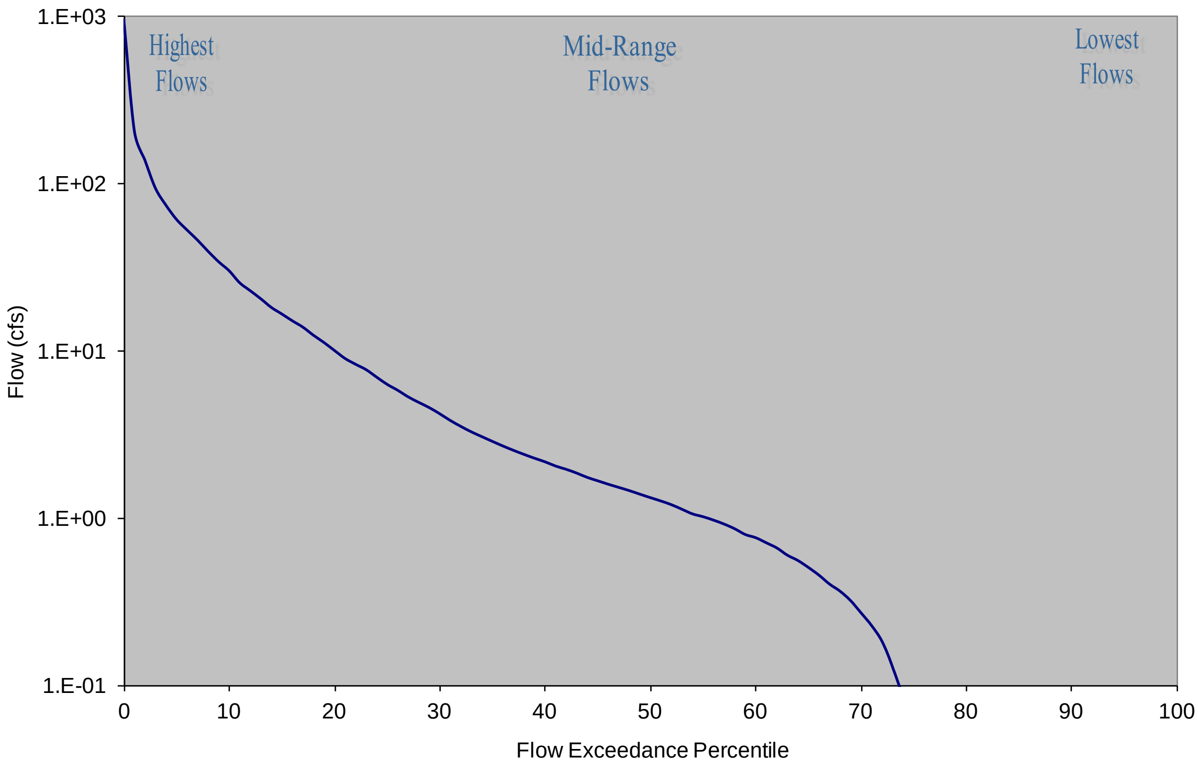

Figure 4-1 Flow Duration Curve for Bintliff Ditch (1007T_01)

Figure 4-2 represents the FDC for Mimosa Ditch, segment 1007U_01 at WQM station 18691. WWTF discharges occur in Mimosa Ditch, thus, average monthly WWTF flows obtained from DMRs were added to the projected naturalized flows. Flows were estimated using USGS gage station 8075000 (Brays Bayou at Houston, TX).

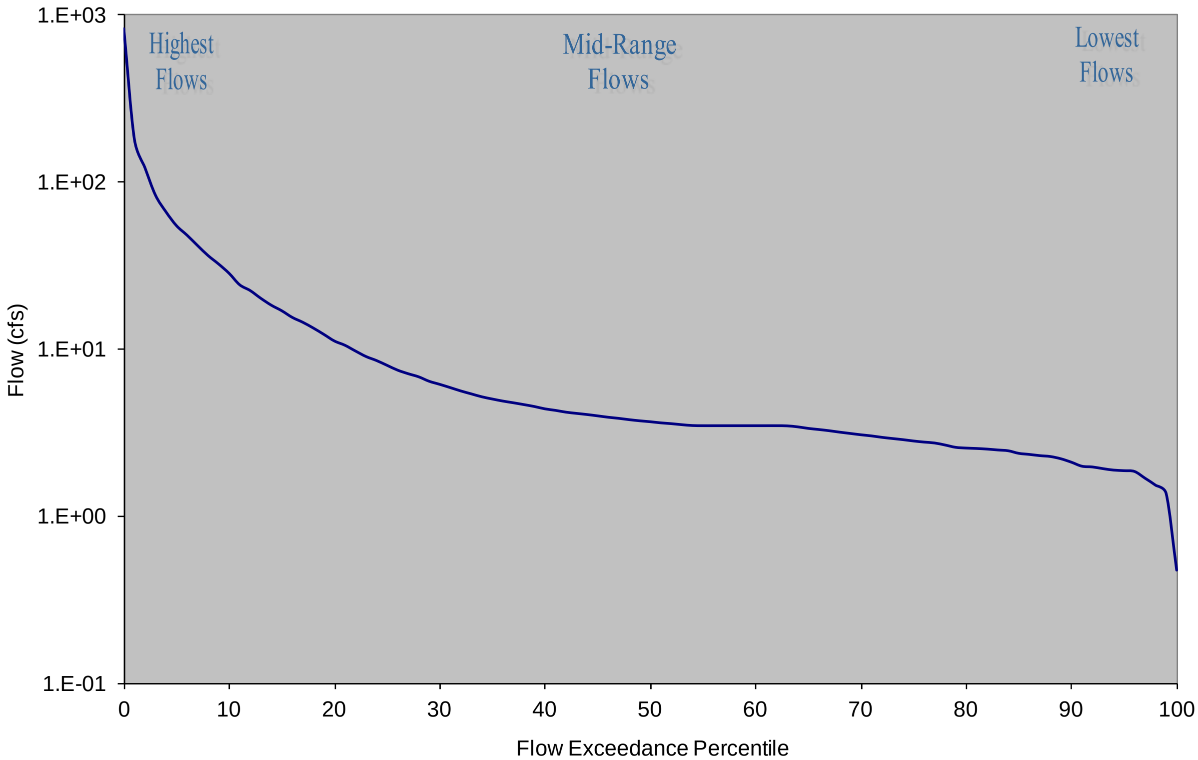

Figure 4-2 Flow Duration Curve for Mimosa Ditch (1007U_01)

Figure 4-3 represents the FDC for Poor Farm Ditch, segment 1007S_01 at WQM station 18692. WWTF discharges occur in Poor Farm Ditch, thus, average monthly WWTF flows obtained from DMRs were added to the projected naturalized flows. Flows were estimated using USGS gage station 8075000 (Brays Bayou at Houston, TX).

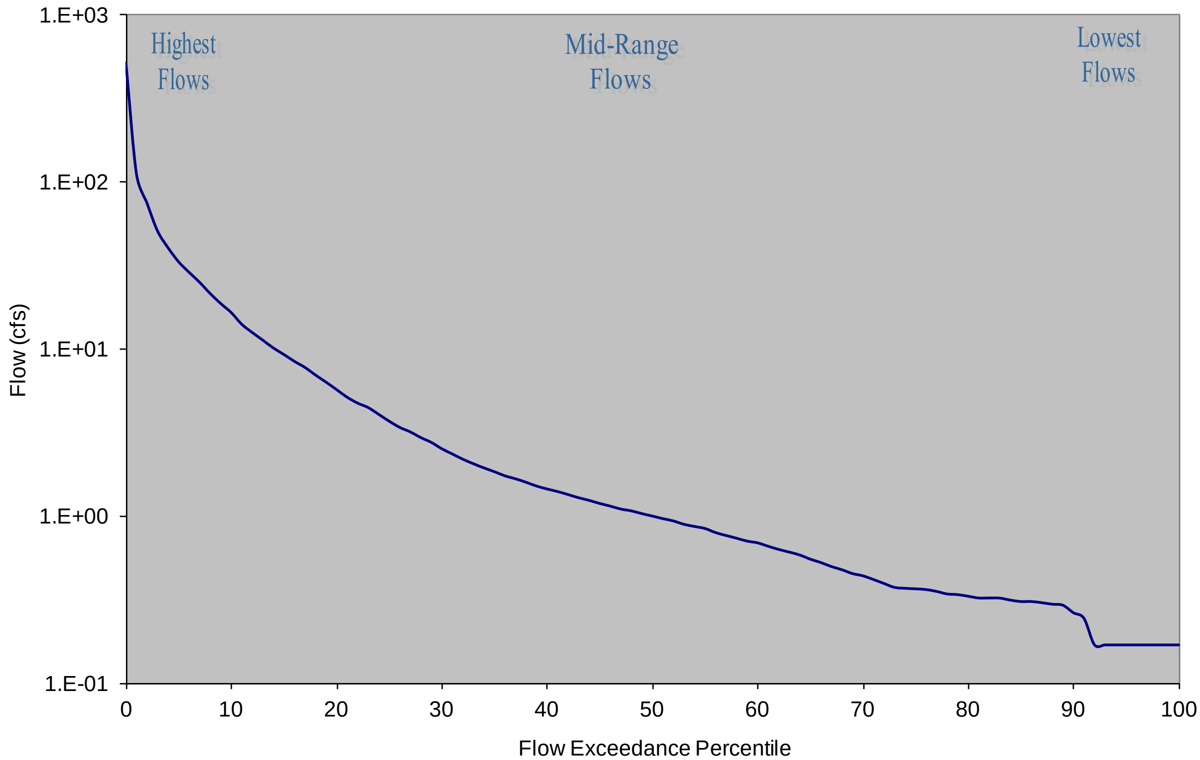

Figure 4-3 Flow Duration Curve for Poor Farm Ditch (1007S_01)

Figure 4-4 represents the FDC for Unnamed Tributary of Hunting Bayou, segment 1007V_01 at WQM station 18689. No WWTF discharges occur in Unnamed Tributary of Hunting Bayou. Flows were estimated using USGS gage station 8075770 (Hunting Bayou at IH 610, Houston, TX).

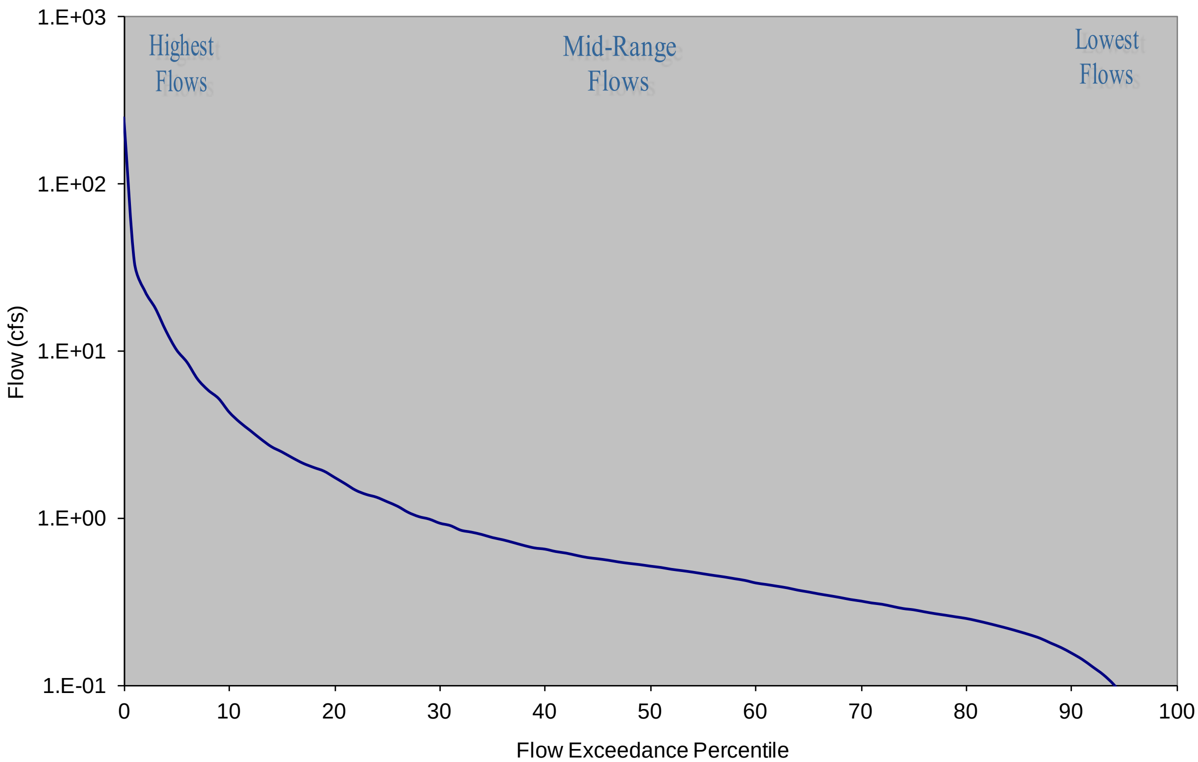

Figure 4-4 Flow Duration Curve for Unnamed Tributary of Hunting Bayou (1007V_01)

Figure 4-5 represents the FDC for Vogel Creek, segment 1017C_01at WQM station 11155. WWTF discharges occur in Vogel Creek, average monthly WWTF flows obtained from DMRs were added to the projected naturalized flows. Flows were estimated using USGS gage station 8074500 (Whiteoak Bayou at Houston, TX).

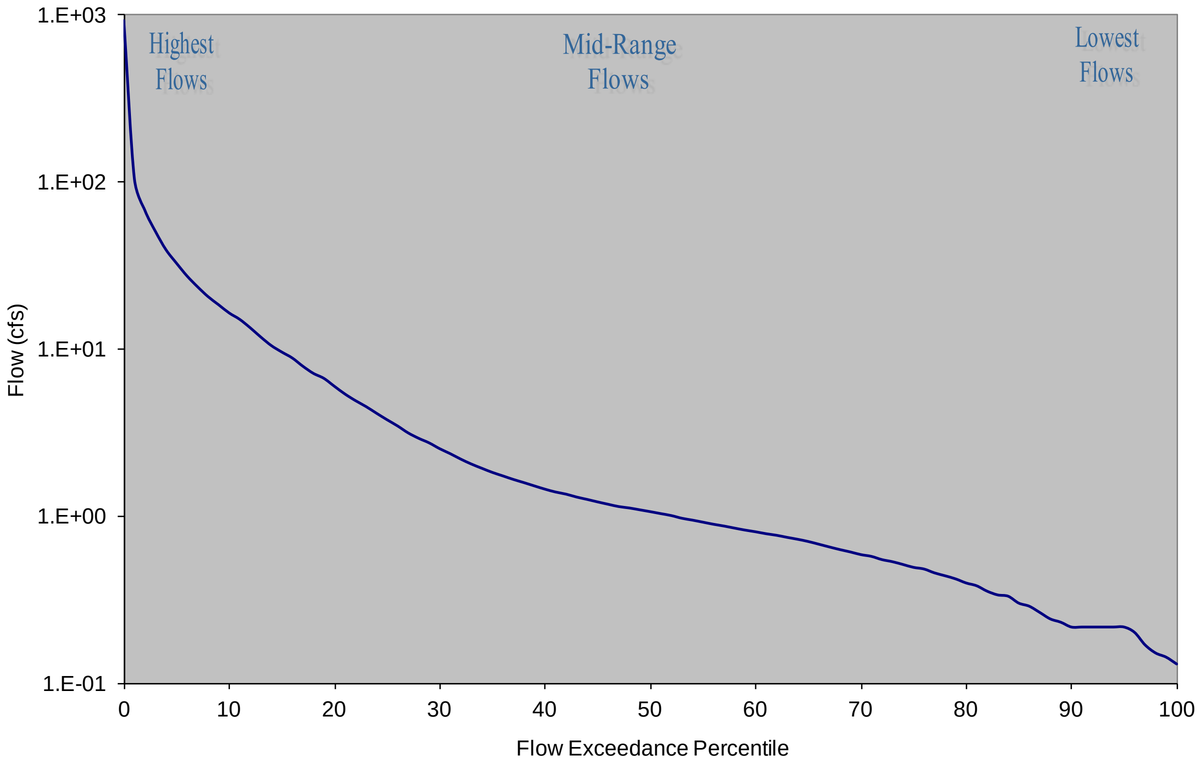

Figure 4-5 Flow Duration Curve for Vogel Creek (1017C_01)

Figure 4-6 represents the FDC for Canal C-147, segment 1007A_01 at WQM station 16656. WWTF discharges occur in Canal C-147, average monthly WWTF flows obtained from DMRs were added to the projected naturalized flows. Flows were estimated using USGS gage station 8075400 (Sims Bayou at Hiram Clarke St, Houston, TX).

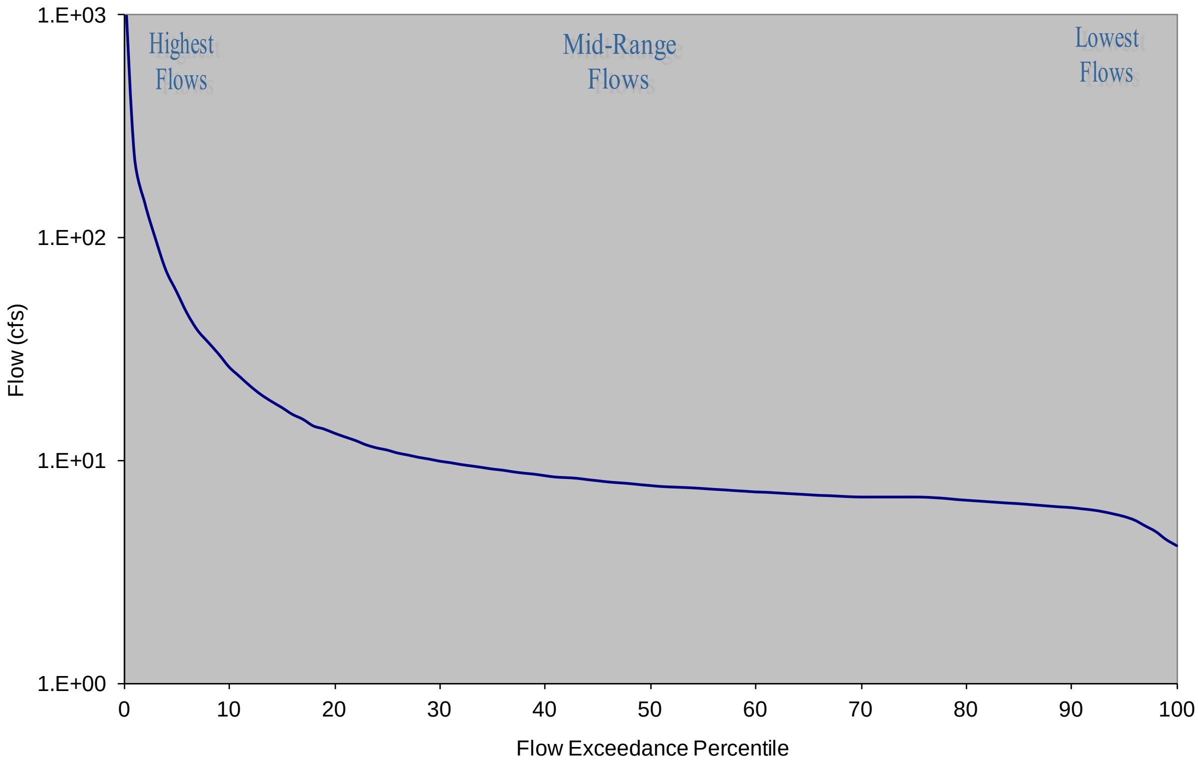

Figure 4-6 Flow Duration Curve for Canal C-147 (1007A_01)

4.3 Estimating Current Point and Nonpoint Loading and Identifying Critical Conditions from Load Duration Curves

Another key step in the use of LDCs for TMDL development is the estimation of existing bacteria loading from point and nonpoint sources and the display of this loading in relation to the TMDL. In Texas, WWTFs that discharge treated sanitary wastewater must meet the criteria for indicator bacteria at the point of discharge. However, for TMDL analysis it is necessary to understand the relative contribution of WWTFs to the overall pollutant load and its general compliance with required effluent limits. The monthly bacteria load for continuous point source dischargers is estimated by multiplying the monthly average flow rates by the monthly geometric mean bacteria concentration, with a volumetric conversion factor. Where available, data necessary for this calculation were extracted from each point source's discharge monitoring reports from 1998 through 2011. The current pollutant loading from each permitted point source discharge is calculated using the equation below:

*Point Source Loading = monthly average flow rates (mgd) * geometric mean of corresponding fecal coliform concentration * unit conversion factor*

Where:

unit conversion factor = 37,854,120 dL/million gallons (mg)

It is difficult to estimate current nonpoint loading due to lack of specific water quality and flow information that would assist in estimating the relative proportion of non-specific sources within the watershed. Therefore, existing instream loads were used as a conservative surrogate for nonpoint loading. Existing instream loads were calculated using measured bacteria concentrations from the WQM station multiplied by the flow rate (estimated or instantaneous) under various flow conditions.

4.4 Development of Bacteria TMDLs Using Load Duration Curves

The final step in the TMDL calculation process involves a group of additional computations derived from the preparation of LDCs. These computations are necessary to derive a percent reduction goal (one method of presenting how much bacteria loading must be reduced to meet the water quality criterion in an impaired watershed).

Step 1: Generate Bacteria LDCs. LDCs are similar in appearance to flow duration curves; however, the ordinate is expressed in terms of a bacteria load in counts/day. The curve represents the instantaneous water quality criterion for *E. coli* (399 counts/dL), expressed in terms of a load through multiplication by the continuum of flows historically observed at this site. Using the single sample water quality criterion to generate the LDC is necessary to display the allowable pollutant load in relation to the existing loads which are represented by existing ambient water quality samples. The basic steps to generating an LDC involve:

- obtaining daily flow data for the WQM station of interest from the USGS;
- sorting the flow data and calculating flow exceedance percentiles for the time period and season of interest;
- obtaining the water quality data;
- matching the water quality observations with the flow data from the same date;
- display a curve on a plot that represents the allowable load by multiplying the actual or estimated flow by the SWQS for each respective indicator;
- multiplying the flow by the water quality parameter concentration to calculate estimated daily loads; then
- plotting the flow exceedance percentiles and daily load observations in a load duration plot.
- The culmination of these steps is expressed in the following formula, which is displayed on the LDC as the TMDL curve:

*TMDL (counts/day) = criterion * flow (cfs) * unit conversion factor*

Where: criterion = 399 counts/dL (E. coli) and

*unit conversion factor = 24,465,755 dL/ft3 * seconds/day*

The flow exceedance frequency (x-value of each point) is obtained by looking up the historical exceedance frequency of the measured or estimated flow; in other words, the percent of historical observations that equal or exceed the measured or estimated flow. Historical observations of bacteria concentration are paired with flow data and are plotted on the LDC. The indicator bacteria load (or the y-value of each point) is calculated by multiplying the indicator bacteria concentration (counts/dL) by the instantaneous flow (cubic feet per second [cfs]) at the same site and time, with appropriate volumetric and time unit conversions. Indicator bacteria loads representing exceedance of water quality criterion fall above the water quality criterion line.

Figure 4-2 provides a schematic representation of where permitted and non-permitted sources of pollution occur throughout the entire hydrograph for a typical stream. This figure shows that runoff typically contributes pollutant loads during high flow to mid-ranged flow conditions. However, flows do not always correspond directly to runoff events. For instance, high flows may occur in dry weather and runoff influence may be observed with low or moderate flows.

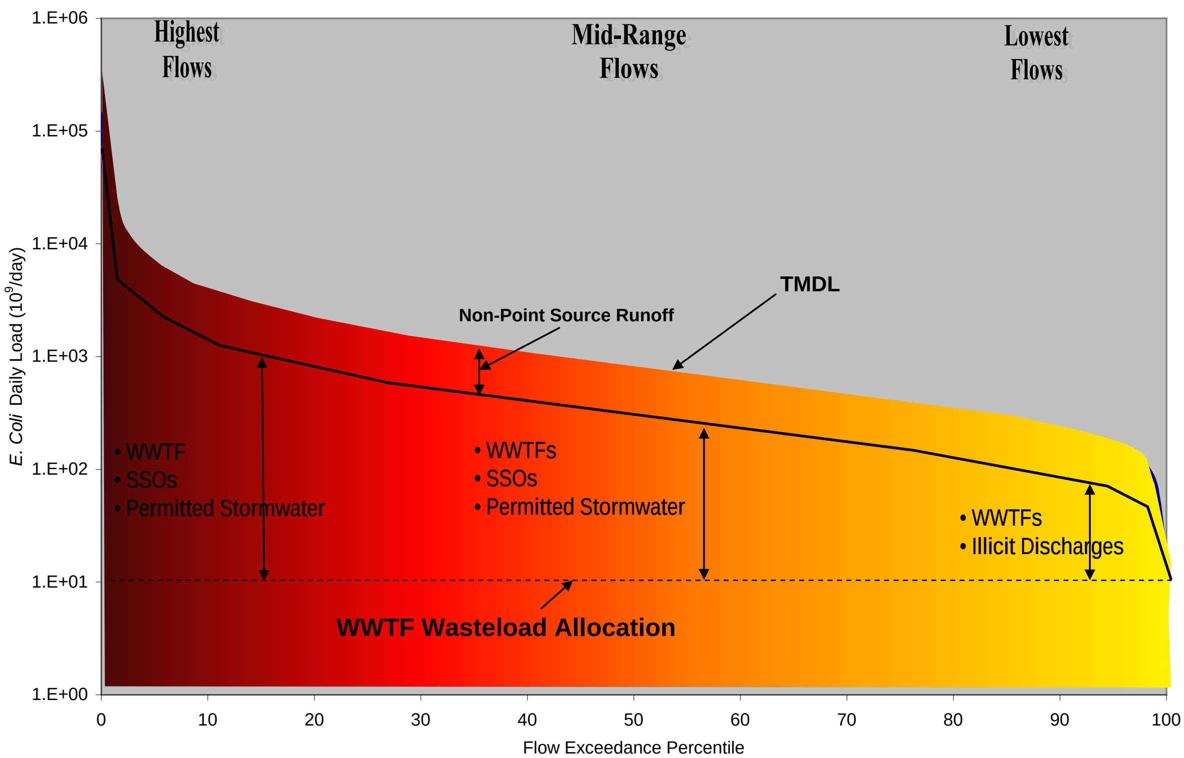

Figure 4-2 LDC Schematic Diagram – Interpreting Sources and Loads

To determine if a bacteria sample was influenced by runoff, rainfall data from the rain gage closest to a WQM station were evaluated. The potential maximum retention after runoff begins (S) was calculated to determine how much rainfall would be needed to produce runoff for each watershed. S is calculated using the formula below:

$$S = \frac{1000}{CN} - 10$$

Where: S = potential maximum retention after runoff begins (inches)

CN =average curve number for the watershed

Three day rainfall totals were then calculated for each rain gage. This data was matched to the date which the bacteria sample was collected. A bacteria sample was then considered a wet weather sample if the three day rainfall total was greater than or equal to S. These bacteria samples were then plotted in the LDCs using a different symbol from those samples that were not considered wet weather influenced.

Step 2: Develop LDCs with MOS. The MOS may be defined explicitly or implicitly. An LDC depicting slightly lower estimates than the TMDL is typically developed to incorporate an MOS into the TMDL calculations. A typical explicit approach would reserve some fraction of the TMDL (*e.g.,* 5%) as the MOS. In an implicit MOS approach, conservative assumptions used in developing the TMDL are relied upon to provide an MOS to assure that standard for contact recreation is attained.

For the TMDLs in this report, an explicit MOS of 5 percent of the TMDL value (5% of the instantaneous water quality criterion) has been selected to slightly reduce assimilative capacity in the watershed. The MOS at any given percent flow exceedance, therefore, is defined as the difference in loading between the TMDL and the TMDL with MOS.

Step 3: Calculate WLA. As previously stated, the pollutant load allocation for permitted (point) sources is defined by the WLA. A point source can be either a wastewater (continuous) or storm water permitted discharge. Storm water point sources are typically associated with urban and industrialized areas, and recent USEPA guidance includes NPDES-permitted storm water discharges as point source discharges and, therefore, part of the WLA.

The LDC approach recognizes that the assimilative capacity of a waterbody depends on the flow, and that maximum allowable loading will vary with flow condition. TMDLs can be expressed in terms of maximum allowable concentrations, or as different maximum loads allowable under different flow conditions, rather than single maximum load values. This concentration-based approach meets the requirements of 40 CFR, 130.2(i) for expressing TMDLs “in terms of mass per time, toxicity, or other appropriate measures” and is consistent with USEPA’s Protocol for Developing Pathogen TMDLs (USEPA 2001).

WLA for WWTF. WLAs may be set to zero for watersheds with no existing or planned continuous permitted point sources. For watersheds with permitted point sources, WLAs may be derived from TPDES permit limits. A WLA may be calculated for each active TPDES wastewater discharger using a mass balance approach as shown in the equation below. The permitted average flow rate used for each point source discharge and the water quality criterion concentration are used to estimate the WLA for each wastewater facility. Through TPDES permits WLAs for WWTFs are constant across all flow conditions and ensure that WQS will be attained (USEPA 2007). All WLA values for each TPDES wastewater discharger are then summed to represent the total WLA for the watershed.

*WLA = criterion * flow * unit conversion factor (#/day)*

Where: criterion = 126/2 counts/dL (E. coli)); flow (mgd) = permitted flow;

unit conversion factor = 37,854,120-dL/ mgd

WLA for NPDES/TPDES MS4s. Given the lack of data and the complexity of quantifying bacteria concentrations or loads associated with wet weather events, calculating the WLA for permitted storm water (MS4) discharges must be derived in a manner similar to that used for all other non-permitted nonpoint sources. In other words it must be derived from the overall LA or the area under the TMDL curve and above the WLA established for WWTFs. Rather than one discrete value, which is practical for WWTF discharges, the WLA calculations for permitted storm water discharges must be expressed as different maximum loads allowable under different flow conditions. Therefore, the percentage of a watershed that is under MS4 jurisdiction is used to estimate the load that should be allocated as the permitted storm water load. The City of Houston/Harris County permitted MS4 discharge covers 100 percent of the subwatersheds addressed in the Study Area. Therefore, 100 percent of the LA calculated at any flow condition for each subwatershed will be designated as part of the the WLA-STORM WATER for the City of Houston/Harris County permitted storm water discharge. The WLA for Storm Water can be expressed as a value for each flow exceedance frequency.

Step 4: Calculate LA. LAs for non-permitted sources (nonpoint sources) can be calculated under different flow conditions as the water quality target load minus the sum of WLA for WWTFs (if any) and permitted storm water (or MS4). The LA is represented by the area under the LDC but above the WLA. The LA at any particular flow exceedance is calculated as shown in the equation below.

$$LA = TMDL - MOS - \Sigma WLA_{WWTF} - \Sigma WLA_{STORM\ WATER}$$

Where:

LA = allowable load from non-permitted sources
$TMDL$ = total allowable load
ΣWLA_{WWTF} = sum of all WWTF loads
$\Sigma WLA_{STORM\ WATER}$ = sum of all MS4 loads
MOS = margin of safety

Step 5: Estimate WLA Load Reduction. The WLA load reduction for TPDES-permitted WWTFs was not calculated since it was assumed that continuous dischargers are adequately regulated under existing permits and, therefore, no WLA reduction would be required. However, for permitted storm water the load reduction will be the same as the percent reduction goal established for the LA (nonpoint sources).

Step 6: Estimate LA Load Reduction. A percent reduction goal is derived for each subwatershed addressed in the Study Area. After existing loading estimates are computed for the applicable indicator bacteria (fecal coliform or *E. coli*), nonpoint load reduction estimates for each sampling location are calculated by using the difference between estimated existing loading and the allowable load expressed by the LDC (TMDL-MOS). Existing loads were determined by using the median flow (10^{th}, $50^{th,}$ and 90^{th} flow exceedance percentile) of each of the three flow regimes multiplied by the geometric mean concentration of the historical bacteria data. For example, for the 0-20_{th} percentile flow range, the flow corresponding to the 10_{th} percentile was used. The geometric mean of the indicator bacteria samples within the 0-20^{th} flow percentile range was then multiplied by the 10^{th} flow exceedance percentile to determine the existing load. Overall, percent reduction goals were also calculated for the most-downstream station of each segment. The highest reduction determined for each segment is then applied as the percent reduction goal. In this case, all indicator bacteria data from flow exceedance percentiles of 0 through 100 were used to calculate the geometric mean and the percent reduction goal was derived using the formula of:

Percent Reduction Goal = (Geometric Mean of Indicator Bacteria Data – Water Quality Target) 100*

CHAPTER 5
TMDL CALCULATIONS

5.1 Estimated Loading and Critical Conditions

USEPA regulations at 40 CFR 130.7(c) (1) require TMDLs to take into account critical conditions for stream flow, loading, and all applicable water quality standards. To accomplish this, available instream WQM data were evaluated with respect to stream flows and the magnitude of water quality criteria exceedance. TMDLs are derived for specific indicator bacteria in 303(d) listed water bodies at specific WQM stations based on LDCs.

To calculate the bacteria load at the criterion, the flow rate at each flow exceedance percentile is multiplied by a unit conversion factor (*24,465,755 dL/ft3 * seconds/day*) and the *E. coli* criterion. This calculation produces the maximum bacteria load in the stream without exceeding the instantaneous standard over the range of flow conditions. *E. coli* loads are plotted versus flow exceedance percentiles as a LDC. The x-axis indicates the flow exceedance percentile, while the y-axis is expressed in terms of a bacteria load.

To estimate existing loading, bacteria observations from 2001 to 2011 are paired with the flows measured or estimated in that segment on the same date. Pollutant loads are then calculated by multiplying the measured bacteria concentration by the flow rate and a unit conversion factor of *24,465,755 dL/ft3 * seconds/day*. The associated flow exceedance percentile is then matched with the measured flow from the tables provided in Appendix E. The observed bacteria loads are then added to the LDC plot as points. These points represent individual ambient water quality samples of bacteria. Points above the LDC indicate the bacteria instantaneous standard was exceeded at the time of sampling. Conversely, points under the LDC indicate the sample met the criterion.

The LDC approach recognizes that the assimilative capacity of a waterbody depends on the flow, and that maximum allowable loading varies with flow condition. Existing loading, and load reductions required to meet the TMDL water quality target can also be calculated under different flow conditions. The difference between existing loading and the water quality target is used to calculate the loading reductions required.

Percent reduction goals for each 303(d)-listed waterbody in the Study Area are based on data analysis using the geometric mean criterion since it is anticipated that achieving the geometric mean over an extended period of time will likely ensure that the single sample criterion will also be achieved. Because the geometric mean criterion is considered more stringent, the TMDL for each of these sampling locations is determined by selecting the highest percent reduction goal calculated for the geometric mean criterion.

The TMDL percent reduction goals for Bintliff Ditch (1007T_01), Mimosa Ditch (1007U_01), Poor Farm Ditch (1007S_01), Unnamed Tributary of Hunting Bayou (1007V_01), Vogel Creek (1017C_01), and Canal C-147 (1007A_01) are based on the geometric mean criterion. The pollutant load allocations and percent reduction goals for each flow regime are summarized in Section 5.7. The highest percent reduction goals for each segment were found to occur in the flow regime with the highest flows (0–20th percentile). The percent reduction goals for the highest flows ranged from 66 to 98 percent. However, the overall percent reduction goal, which is calculated as the reduction required for the geometric mean of all the observed data to reach the geometric mean criterion, was ranged from 81 to 99 percent.

Figure 5-1 represents the LDC for Bintliff Ditch (1007T_01) and is based on *E. coli* bacteria measurements at sampling location 18690 (Bintliff Ditch at Bissonnet). The LDC indicates that *E. coli* levels exceed the instantaneous and geometric mean water quality criteria under high and mid-range flow conditions. Wet weather influenced *E. coli* observations are found under high and mid-range flow conditions.

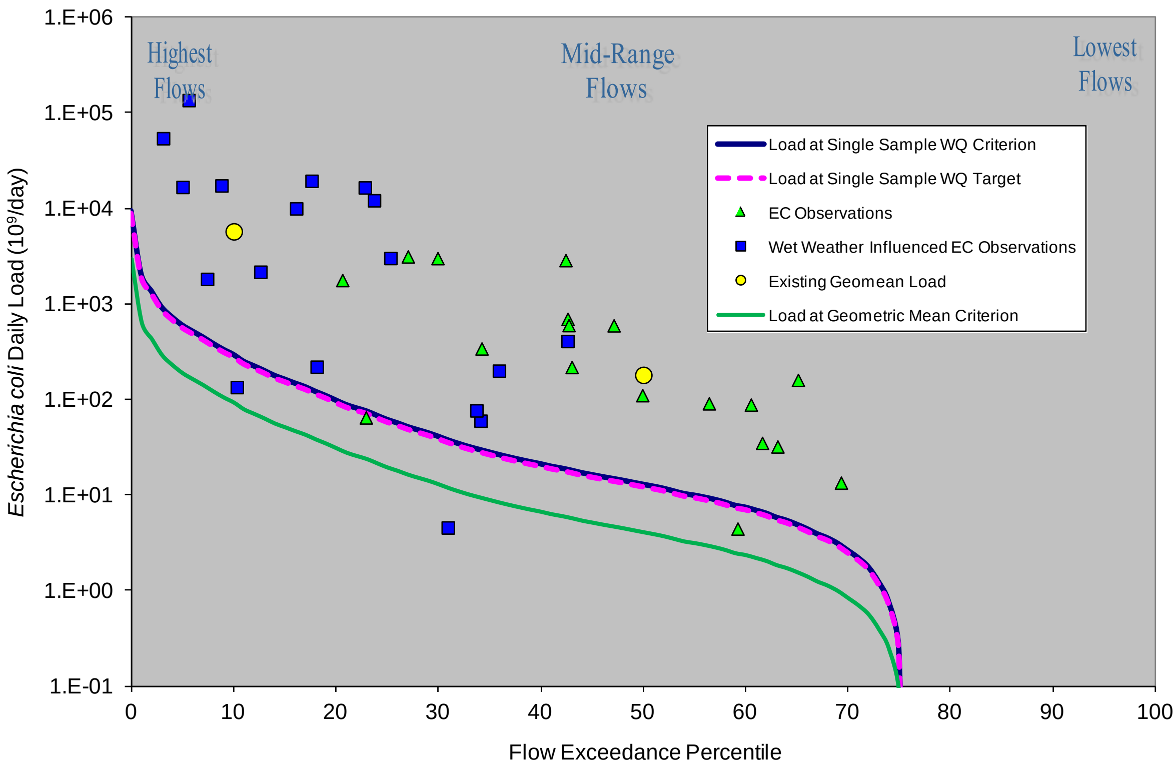

Figure 5-1 Load Duration Curve for Bintliff Ditch (1007T_01)

Figure 5-2 represents the LDC for Mimosa Ditch (1007U_01) and is based on *E. coli* bacteria measurements at sampling location 18691 (Mimosa Ditch at Newcastle Dr.). The LDC indicates that *E. coli* levels exceed the instantaneous and geometric mean water quality criteria under all flow conditions. Wet weather influenced *E. coli* observations are found under high and mid-range flow conditions.

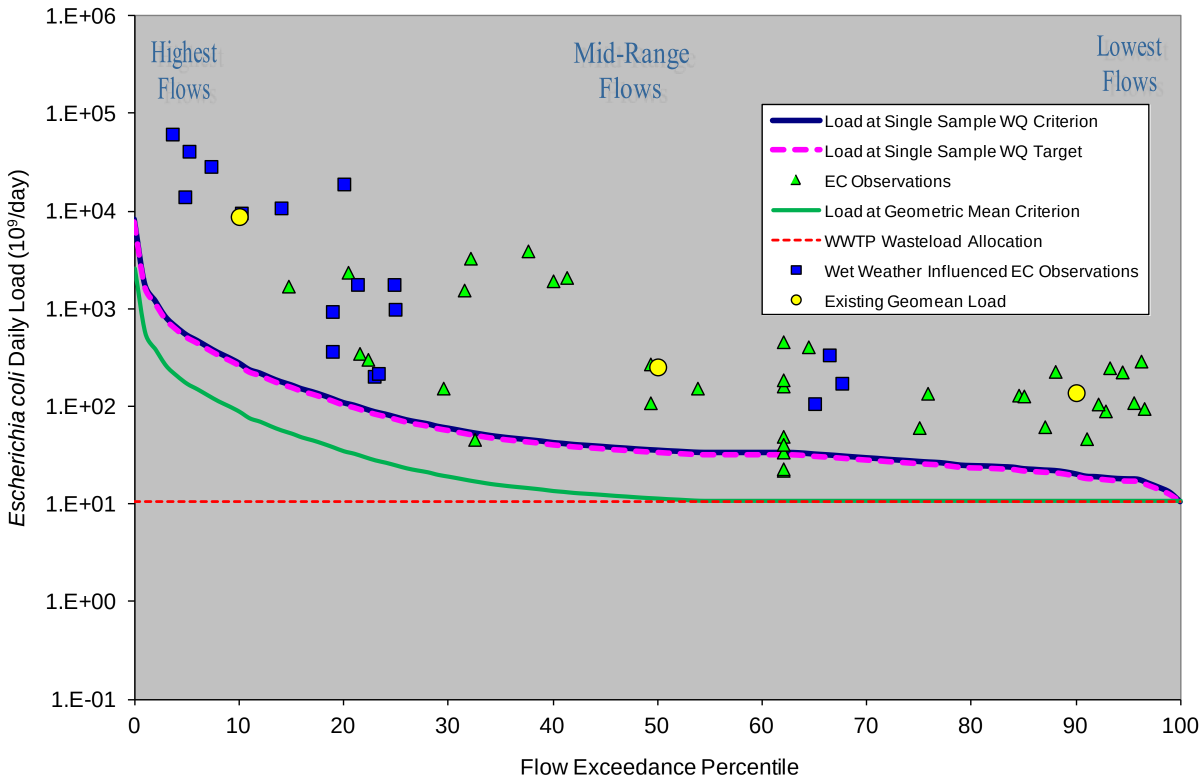

Figure 5-2 Load Duration Curve for Mimosa Ditch (1007U_01)

Figure 5-3 represents the LDC for Poor Farm Ditch (1007S_01) and is based on *E. coli* bacteria measurements at sampling location 18692 (Poor Farm Ditch at N Braeswood). The LDC indicates that *E. coli* levels exceed the instantaneous and geometric mean water quality criteria under all flow conditions. Wet weather influenced *E. coli* observations are found under all flow conditions.

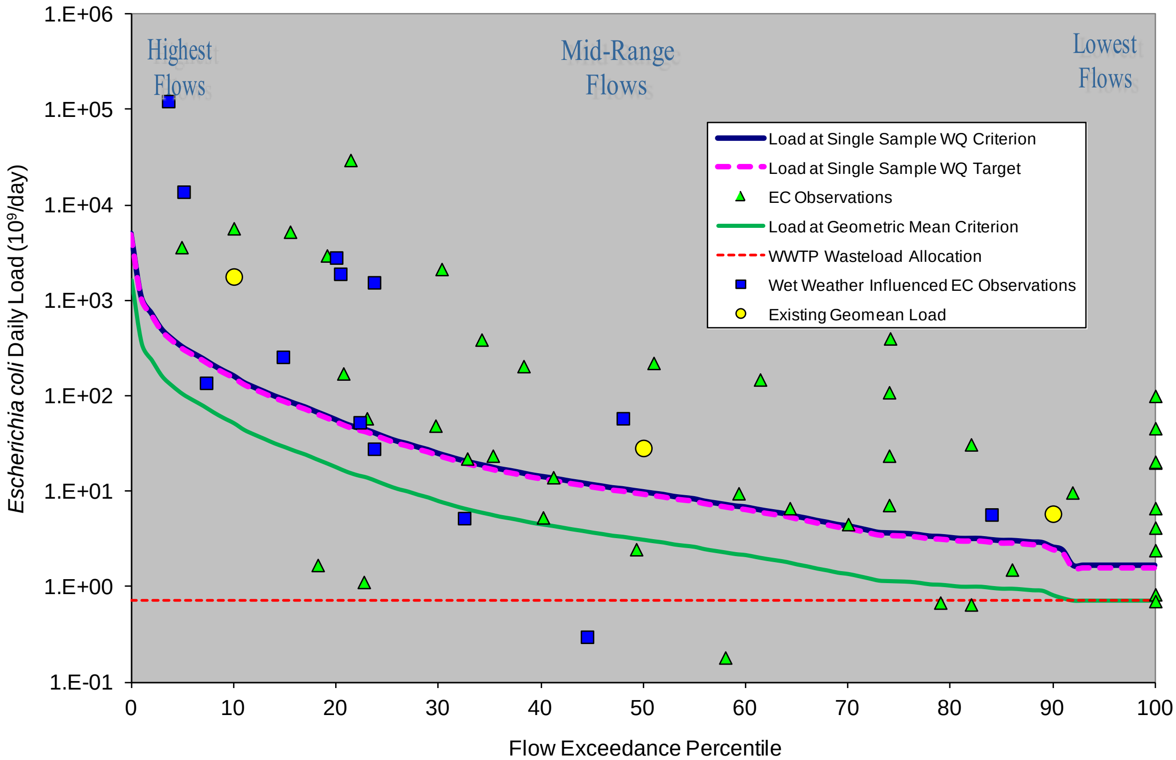

Figure 5-3 Load Duration Curve for Poor Farm Ditch (1007S_01)

Figure 5-4 represents the LDC for Unnamed Tributary of Hunting Bayou (1007V_01) and is based on *E. coli* bacteria measurements at sampling location 18689 (Tributary Hunting Bayou at Minden). The LDC indicates that *E. coli* levels exceed the instantaneous and geometric mean water quality criteria under all flow conditions. Wet weather influenced *E. coli* observations are found under high and mid-range flow conditions.

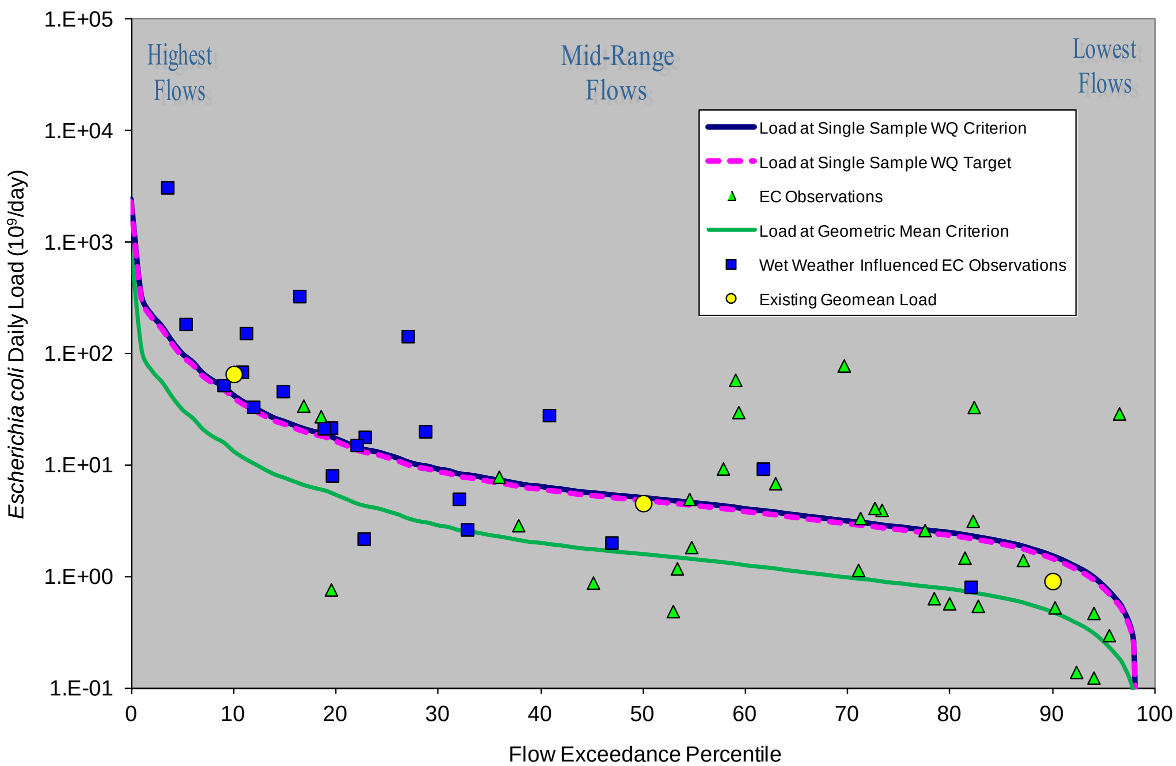

Figure 5-4 Load Duration Curve for Unnamed Tributary of Hunting Bayou (1007V_01)

Figure 5-5 represents the LDC for Vogel Creek (1017C_01) and is based on *E. coli* bacteria measurements at sampling location 11155 (Vogel Creek at Little York Rd.). The LDC indicates that *E. coli* levels exceed the instantaneous water quality criterion under high and mid-range flow conditions and the geometric mean criterion under high flow conditions. Wet weather influenced *E. coli* observations are found under all flow conditions.

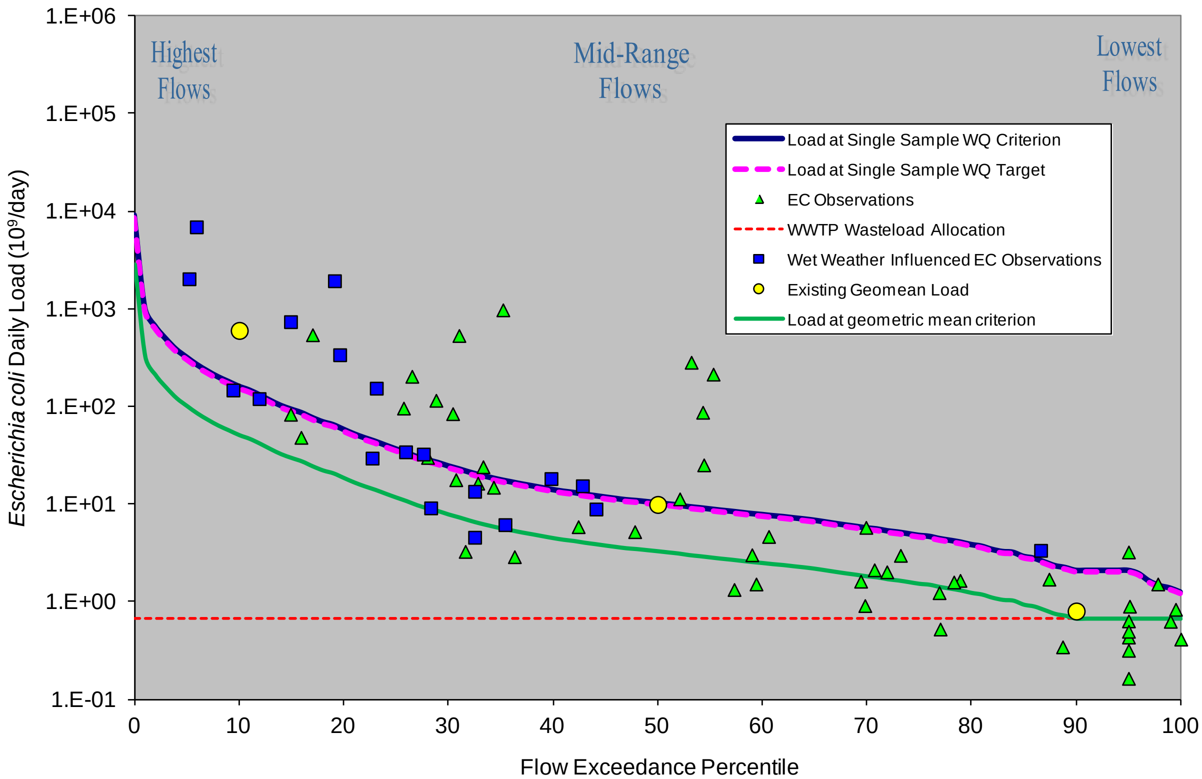

Figure 5-5 Load Duration Curve for Vogel Creek (1017C_01)

Figure 5-6 represents the LDC for Canal C-147 (1007A_01) and is based on *E. coli* bacteria measurements at sampling location 16656 (Sims Bayou South Branch at Tiffany Drive in South Houston). The LDC indicates that *E. coli* levels exceed the instantaneous and geometric mean water quality criteria under high and mid-range flow conditions. Wet weather influenced *E. coli* observations are found under all flow conditions.

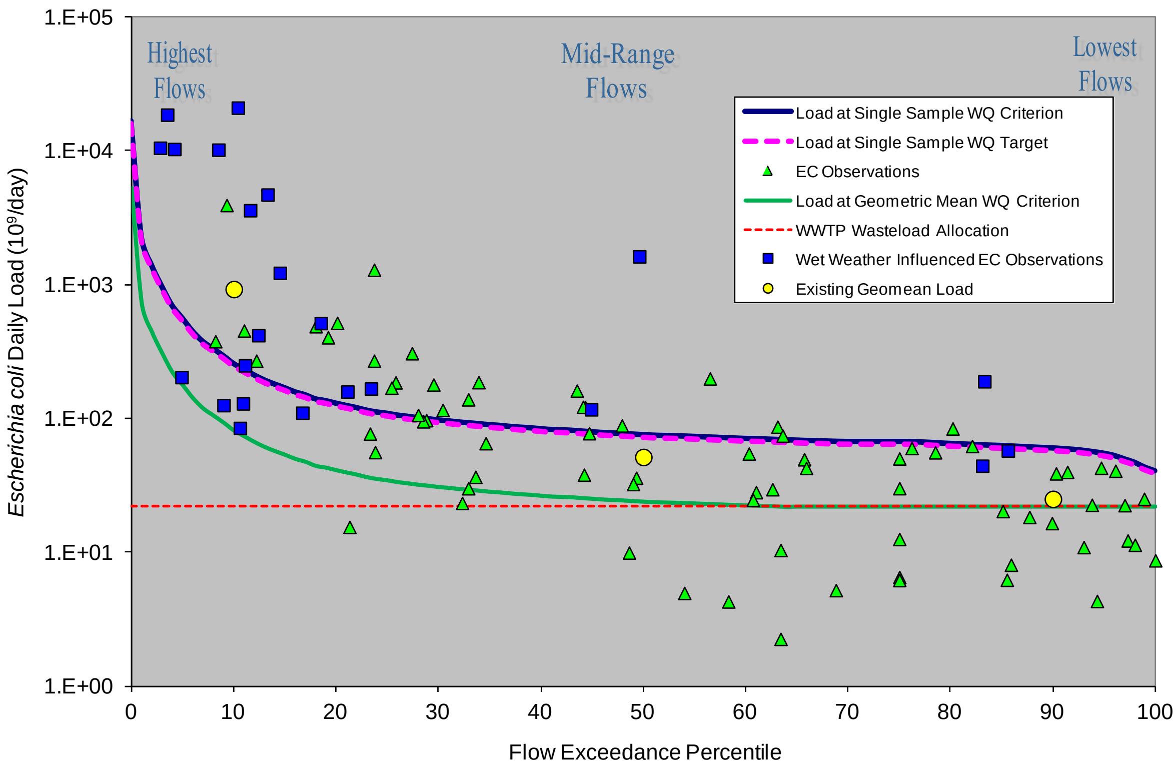

Figure 5-6 Load Duration Curve for Canal C-147 (1007A_01)

5.2 Wasteload Allocation

TPDES-permitted facilities are allocated a daily wasteload calculated as their permitted discharge flow rate multiplied by the instream geometric mean water quality criterion. In other words, the facilities are required to meet instream criteria at their points of discharge. Table 5-1 summarizes the WLA for the TPDES-permitted facilities within the Study Area. The WWTFs will not be subject to all listed indicator bacteria. The WLA for each facility (WLA_{WWTF}) is derived from the following equation:

WLA_{WWTF} = *criterion * flow * unit conversion factor (#/day)*

Where:

criterion = 126/2 counts/dL E. coli (half of the WQ standard is used to be consistent with existing TMDLs) *flow (10^6 gal/day) = permitted flow*

unit conversion factor = 37,854,120-10^6gal/day

When multiple TPDES facilities occur within a watershed, loads from individual WWTFs are summed and the total load for continuous point sources is included as part of the WLA_{WWTF} component of the TMDL calculation for the corresponding segment. When there are no TPDES WWTFs discharging into the contributing watershed of a WQM station, then WWTF WLA is zero. Compliance with the WLA_{WWTF} will be achieved by adhering to the fecal coliform discharge limits and disinfection requirements of TPDES permits.

Storm water discharges from MS4 areas are considered permitted point sources. Therefore, the WLA calculations must also include an allocation for permitted storm water discharges. Given the limited amount of data available and the complexities associated with simulating rainfall runoff and the variability of storm water loading a simplified approach for estimating the WLA_{MS4} areas was used in the development of these TMDLs. The percentage of each watershed that is under a TPDES MS4 permit is used to estimate the amount of the overall runoff load that should be dedicated as the permitted storm water contribution in the $WLA_{STORM\ WATER}$ component of the TMDL. The difference between the total storm water runoff load and the portion allocated to $WLA_{STORM\ WATER}$ constitutes the LA component of the TMDL (direct nonpoint runoff).

Table 5-1 Wasteload Allocations for TPDES-Permitted Facilities

Segment	Receiving Water	TPDES Number	NPDES NUMBER	Facility Name	Permitted Flow (MGD)	E.Coli (counts/day)
1007U_01	Mimosa Ditch	10550-001	TX0020613	City of Bellaire-WWTP	4.5	1.07E+10
1007S_01	Poor Farm Ditch	14850-001	TX0026972	City of Southside Place	0.3	7.15E+08
1017C_01	Vogel Creek	11005-001	TX0020095	Champ's Water Company,W. Montgomery Subdivision-WWTP	0.28	6.68E+08
1007A_01	Canal C-147	11553-001	TX0053643	Blue Ridge West Mud-WWTP	1.3	3.10E+09
		10495-110	TX0026433	City of Houston(Greenridge)	7.05	1.68E+10
		12073-001	TX0078891	Fort Bend County MUD No.26	0.8	1.91E+09

5.3 Load Allocation

As discussed in Section 3, non-permitted sources of bacteria loading to the receiving streams of each waterbody emanate from a number of different sources. The data analyses demonstrate that exceedances at the WQM stations are the result of a variety of nonpoint source loading. The LAs for each stream segment are calculated as the difference between the TMDL, MOS, WLA, and WLA for storm water as follows:

$$LA = TMDL - \sum WLA_{WWTF} - \sum WLA_{STORM\ WATER} - MOS$$

Where:

LA = allowable load from non-permitted sources
TMDL= total allowable load
ΣWLA_{WWTF} = sum of all WWTF loads
$\sum WLA_{STORM\ WATER}$ = sum of all permitted storm water loads
MOS = margin of safety

5.4 Seasonal Variability

Federal regulations (40 CFR §130.7(c)(1)) require that TMDLs account for seasonal variation in watershed conditions and pollutant loading. Seasonal variation was accounted for in these TMDLs by using more than 5 years of water quality data and by using the longest period of USGS flow records when estimating flows to develop flow exceedance percentiles.

Analysis of the available data for *E. coli* showed that 4 out of 7 stations exhibited higher geometric mean concentrations for the warmer months than the colder months.

5.5 Allowance for Future Growth

Compliance with these TMDLs is based on keeping the indicator bacteria concentrations in the selected waters below the limits that were set as criteria for the individual sites. Future growth of existing or new point sources is not limited by these TMDLs as long as the sources do not cause indicator bacteria to exceed the limits. The assimilative capacity of streams increases as the amount of flow increases. Increases in flow allow for additional indicator bacteria loads if the concentrations are at or below the contact recreation criterion. The addition of any future wastewater discharge facilities will be evaluated on a case-by-case basis. To account for the probability that new additional flows from WWTF may occur in any of the segments, a provision for future growth was included in the TMDL calculations by estimating permitted flows to year 2035 using population projections completed by HGAC (HGAC, 2007).

Table 5-2 shows the population increases in each of the five TMDL assessment units based on the population projections from the H-GAC report. The population increases range from 4 percent to 14 percent. The permitted flows were increased by the expected population growth per assessment unit between 2005 and 2035 to determine the estimated future flows. Future WWTF flows were calculated by multiplying the permitted flow by the increase in population estimated for each assessment unit. The future WWTF flows for each assessment unit were added to the flows from runoff to calculate the TMDL. The allocation for future population growth is the difference between the WWTF loads calculated using estimated future flows and permitted flows.

Table 5-2 Population Projection per Subwatershed

Assessment Unit	Stream Name	2005	2035	Increase
1007T_01	Bintliff Ditch	34,087	35,557	4%
1007U_01	Mimosa Ditch	21,240	22,000	4%
1007S_01	Poor Farm Ditch	15,855	16,670	5%
1007V_01	Unnamed Tributary of Hunting Bayou	3,487	3,976	14%
1017C_01	Vogel Creek	18,638	20,041	8%
1007A_01	Canal C-147	29,568	33,457	13%

5.6 Margin of Safety

Federal regulations (40 CFR §130.7(c)(1)) require that TMDLs include an MOS. The MOS is a conservative measure incorporated into the TMDL equation that accounts for the uncertainty associated with calculating the allowable pollutant loading to ensure geometric mean criterion are attained. USEPA guidance allows for use of implicit or explicit expressions of the MOS, or both. When conservative assumptions are used in development of the TMDL, or conservative factors are used in the calculations, the MOS is implicit. When a specific percentage of the TMDL is set aside to account for uncertainty, then the MOS is considered explicit.

The TMDLs incorporate an explicit MOS by setting a more stringent target for indicator bacteria loads that is 5 percent lower than the single sample criterion. The explicit margin of safety was used because of the limited amount of data. For contact recreation, this equates to a single sample target of 379 MPN/100mL for *E. coli* and a geometric mean target of 120 MPN/100mL. The net effect of the TMDL with MOS is that the assimilative capacity or allowable pollutant loading of each waterbody is slightly reduced. The TMDLs in this report incorporate an explicit MOS in the LDC by using 95 percent of the single sample criterion.

5.7 TMDL Calculations

The bacteria TMDLs for the 303(d)-listed WQM stations covered in this report were derived using LDCs. A TMDL is expressed as the sum of all WLAs (point source loads), LAs (nonpoint source loads), and an appropriate MOS, which attempts to account for uncertainty concerning the relationship between effluent limitations and water quality.

This definition can be expressed by the following equation:

$$TMDL = \Sigma\, WLA + \Sigma\, LA + MOS + Future\ Growth$$

Tables 5-3 through 5-8 summarize the pollutant load allocations and percent reduction goals, for the median flow exceedance percentile of each of the three hydrologic classification categories. The final TMDLs for the six assessment units included in this project are summarized in Table 5-9. The TMDLs were calculated based on the median flow in the 0-20 flow exceedance percentile range, which corresponds to the range requiring the highest percent reductions.

The final TMDL allocations needed to comply with the requirements of 40 CFR 130.7 are presented in Table 5-10. In this table the future capacity for WWTF has been added to the WLA_{WWTF}.

TMDL values and allocations in Table 5-10 are derived from calculations using the existing water quality criterion for *E. coli* and a critical flow condition (median flow of the hydrologic range requiring the greatest pollutant load reduction). However, designated uses and water quality criteria for these water bodies are subject to change through the TCEQ standards revision process. Figures 5-7 through 5-12 were developed to demonstrate how assimilative capacity, TMDL calculations and pollutant load allocations change in relation to a number of hypothetical water quality criteria for *E. coli*. The equations provided along with Figures 5-7 through 5-12 allow calculating new TMDLs and pollutant load allocations based on any potential new water quality criterion for *E. coli*.

Table 5-3 *E. coli* TMDL Calculations for Bintliff Ditch (1007T_01)

Station 18690			
Flow Regime %	**0%-20%**	**20%-80%**	**80%-100%**
Median Flow, Q (cfs)	30.1	1.32	0
Existing Load (10^9 org/day)	5.74E+03	1.81E+02	0
TMDL (Q*C) (10^9 org/day)	9.28E+01	4.07E+00	0
MOS (Q*C*0.05) (10^9 org/day)	4.64E+00	2.04E-01	0
Allowable Load at Water Quality Target, Load Allocation, TMDL-MOS (10^9 org/day)	8.82E+01	3.87E+00	0
Load Reduction (10^9 org/day)	5.65E+03	1.77E+02	0
Load Reduction (%)	**98.5%**	97.9%	0
Overall Load Reduction* (%)	98%		
TMDL (Q_{future}*WQS) (10^9 org/day)	2.94E+02		

Table 5-4 *E. coli* TMDL Calculations for Mimosa Ditch (1007U_01)

Station 18691			
Flow Regime %	**0%-20%**	**20%-80%**	**80%-100%**
Median Flow, Q (cfs)	28.4	3.68	2.10
Existing Load (10^9 org/day)	8.80E+03	2.54E+02	1.38E+02
TMDL (Q*C) (10^9 org/day)	8.77E+01	1.13E+01	6.49E+00
MOS (Q*C*0.05) (10^9 org/day)	4.38E+00	5.67E-01	3.24E-01
Allowable Load at Water Quality Target, Load Allocation, TMDL-MOS (10^9 org/day)	8.33E+01	1.08E+01	6.16E+00
Load Reduction (10^9 org/day)	8.72E+03	2.43E+02	1.32E+02
Load Reduction (%)	**99.1%**	95.8%	95.5%
Overall Load Reduction* (%)	97%		
TMDL (Q_{future}*WQS) (10^9 org/day)	3.24E+02		

Table 5-5 *E. coli* TMDL Calculations for Poor Farm Ditch (1007S_01)

Station 18692			
Flow Regime %	**0%-20%**	**20%-80%**	**80%-100%**
Median Flow, Q (cfs)	16.6	1.00	0.26
Existing Load (10^9 org/day)	1.78E+03	2.85E+01	5.83E+00
TMDL (Q*C) (10^9 org/day)	5.12E+01	3.10E+00	8.17E-01
MOS (Q*C*0.05) (10^9 org/day)	2.56E+00	1.55E-01	4.08E-02
Allowable Load at Water Quality Target, Load Allocation, TMDL-MOS (10^9 org/day)	4.86E+01	2.94E+00	7.76E-01
Load Reduction (10^9 org/day)	1.73E+03	2.55E+01	5.06E+00
Load Reduction (%)	**97.3%**	89.7%	86.7%
Overall Load Reduction* (%)	91%		
TMDL (Q_{future}*WQS) (10^9 org/day)	1.63E+02		

Table 5-6 *E. coli* TMDL Calculations for Unnamed Tributary of Hunting Bayou (1007V_01)

Station 18689			
Flow Regime %	**0%-20%**	**20%-80%**	**80%-100%**
Median Flow, Q (cfs)	4.3	0.52	0.16
Existing Load (10^9 org/day)	6.56E+01	4.55E+00	9.10E-01
TMDL (Q*C) (10^9 org/day)	1.33E+01	1.59E+00	4.81E-01
MOS (Q*C*0.05) (10^9 org/day)	6.64E-01	7.96E-02	2.40E-02
Allowable Load at Water Quality Target, Load Allocation, TMDL-MOS (10^9 org/day)	1.26E+01	1.51E+00	4.57E-01
Load Reduction (10^9 org/day)	5.30E+01	3.04E+00	4.53E-01
Load Reduction (%)	**80.8%**	66.8%	49.8%
Overall Load Reduction* (%)	68%		
TMDL (Q_{future}*WQS) (10^9 org/day)	4.20E+01		

Table 5-7 *E. coli* TMDL Calculations for Vogel Creek (1017C_01)

Station 11155			
Flow Regime %	**0%-20%**	**20%-80%**	**80%-100%**
Median Flow, Q (cfs)	16.4	1.06	0.22
Existing Load (10^9 org/day)	6.01E+02	9.91E+00	8.03E-01
TMDL (Q*C) (10^9 org/day)	5.06E+01	3.27E+00	6.68E-01
MOS (Q*C*0.05) (10^9 org/day)	2.53E+00	1.64E-01	3.34E-02
Allowable Load at Water Quality Target, Load Allocation, TMDL-MOS (10^9 org/day)	4.81E+01	3.11E+00	6.34E-01
Load Reduction (10^9 org/day)	5.53E+02	6.80E+00	1.69E-01
Load Reduction (%)	**92.0%**	68.6%	21.0%
Overall Load Reduction* (%)	69%		
TMDL (Qfuture*WQS) (10^9 org/day)	1.63E+02		

Table 5-8 *E. coli* TMDL Calculations for Canal C-147 (1007A_01)

Station 16656			
Flow Regime %	**0%-20%**	**20%-80%**	**80%-100%**
Median Flow, Q (cfs)	26.3	7.71	6.13
Existing Load (10^9 org/day)	9.28E+02	5.16E+01	2.51E+01
TMDL (Q*C) (10^9 org/day)	8.10E+01	2.38E+01	1.89E+01
MOS (Q*C*0.05) (10^9 org/day)	4.05E+00	1.19E+00	9.45E-01
Allowable Load at Water Quality Target, Load Allocation, TMDL-MOS (10^9 org/day)	7.69E+01	2.26E+01	1.80E+01
Load Reduction (10^9 org/day)	8.51E+02	2.90E+01	7.09E+00
Load Reduction (%)	**91.7%**	56.2%	28.3%
Overall Load Reduction* (%)	66%		
TMDL (Qfuture*WQS) (10^9 org/day)	3.45E+02		

Table 5-9 *E. coli* TMDL Summary Calculations for Study Area Assessment Units

Assessment Unit	Stream Name	TMDL[a] (MPN/day)	WLA_{WWTF}[b] (MPN/day)	$WLA_{STORM\ WATER}$[c] (MPN/day)	LA[d] (MPN/day)	MOS[e] (MPN/day)	Future Growth[f] (MPN/day)
1007T_01	Bintliff Ditch	2.94E+11	0	2.79E+11	0	1.47E+10	0
1007U_01	Mimosa Ditch	3.24E+11	1.07E+10	2.97E+11	0	1.62E+10	4.29E+08
1007S_01	Poor Farm Ditch	1.63E+11	7.15E+08	1.54E+11	0	8.13E+09	3.58E+07
1007V_01	Unnamed Tributary of Hunting Bayou	4.20E+10	0	3.99E+10	0	2.10E+09	0
1017C_01	Vogel Creek	1.63E+11	6.68E+08	1.54E+11	0	8.14E+09	5.34E+07
1007A_01	Canal C-147	3.45E+11	2.18E+10	3.03E+11	0	1.72E+10	2.84E+09

[a] Maximum allowable load for the flow range requiring the highest percent reduction (Tables 5-3 through 5-8)
*[b] Sum of loads from the WWTF discharging upstream of the TMDL station. Individual loads are calculated as permitted flow * 126/2 (E. coli) MPN/100mL*conversion factor (Table 5-1)*
[c] $WLA_{STORM\ WATER}$ *= (TMDL – MOS –* WLA_{WWTF}*)*(percent of drainage area covered by storm water permits)*
[d] LA = TMDL – MOS – WLA_{WWTF} *–* $WLA_{STORM\ WATER}$*-Future growth*
[e] MOS = TMDL x 0.05
*[f] Projected increase in WWTF permitted flows*126/2*conversion factor*

Table 5-10 Final TMDL Allocations

Assessment Unit	TMDL (cfu/day)	WLA_{WWTF}[a] (MPN/day)	$WLA_{STORM\ WATER}$ (cfu/day)	LA (cfu/day)	MOS (cfu/day)
1007T_01	2.94E+11	0	2.79E+11	0	1.47E+10
1007U_01	3.24E+11	1.12E+10	2.97E+11	0	1.62E+10
1007S_01	1.63E+11	7.51E+08	1.54E+11	0	8.13E+09
1007V_01	4.20E+10	0	3.99E+10	0	2.10E+09
1017C_01	1.63E+11	7.21E+08	1.54E+11	0	8.14E+09
1007A_01	3.45E+11	2.47E+10	3.03E+11	0	1.72E+10

[a] WLA_{WWTF}*=* WLA_{WWTF} *(Table 5-9) + Future Growth (Table 5-9)*

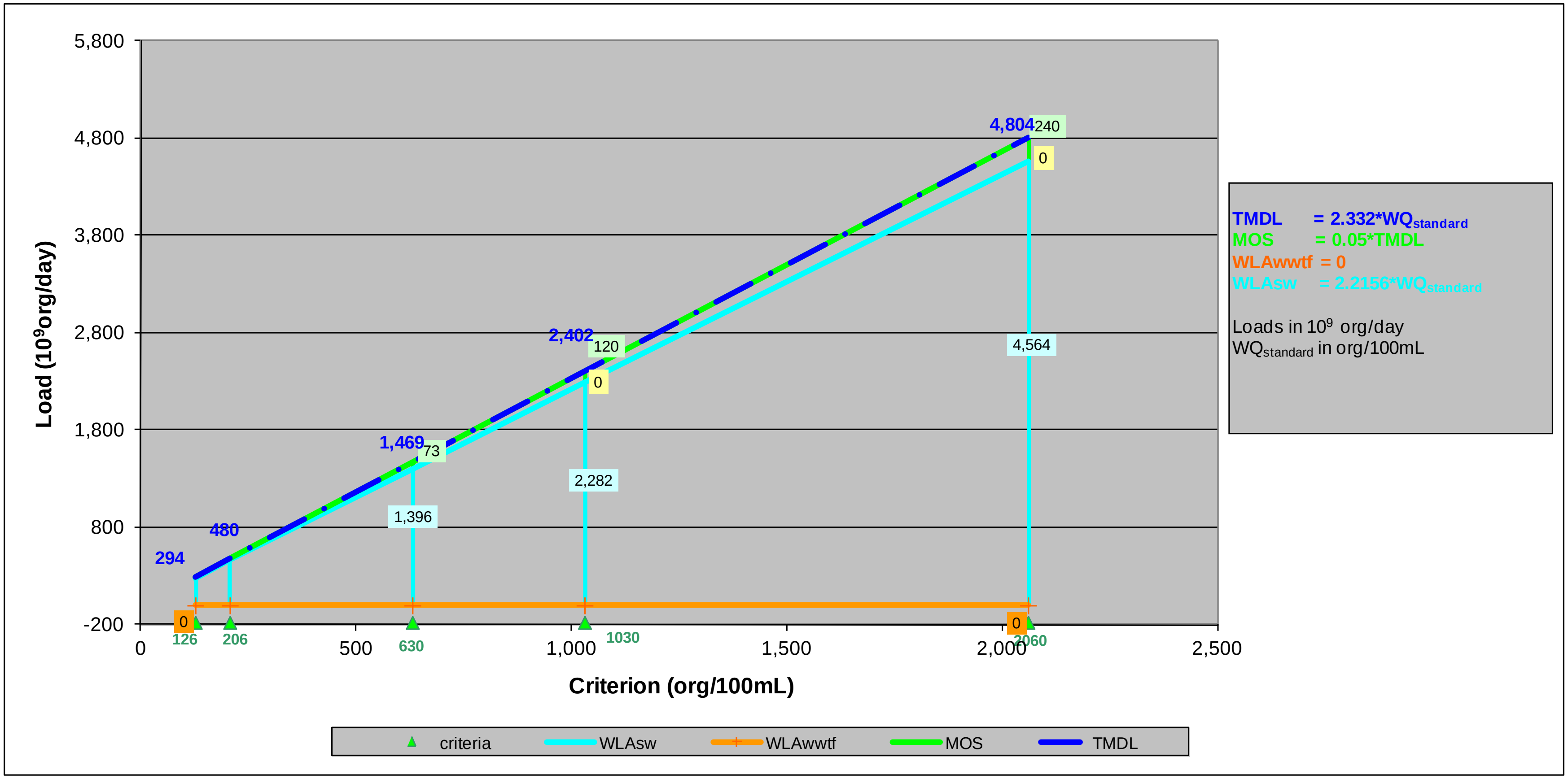

Figure 5-7 Allocation Loads for AU 1007T_01 as a Function of WQ Criteria

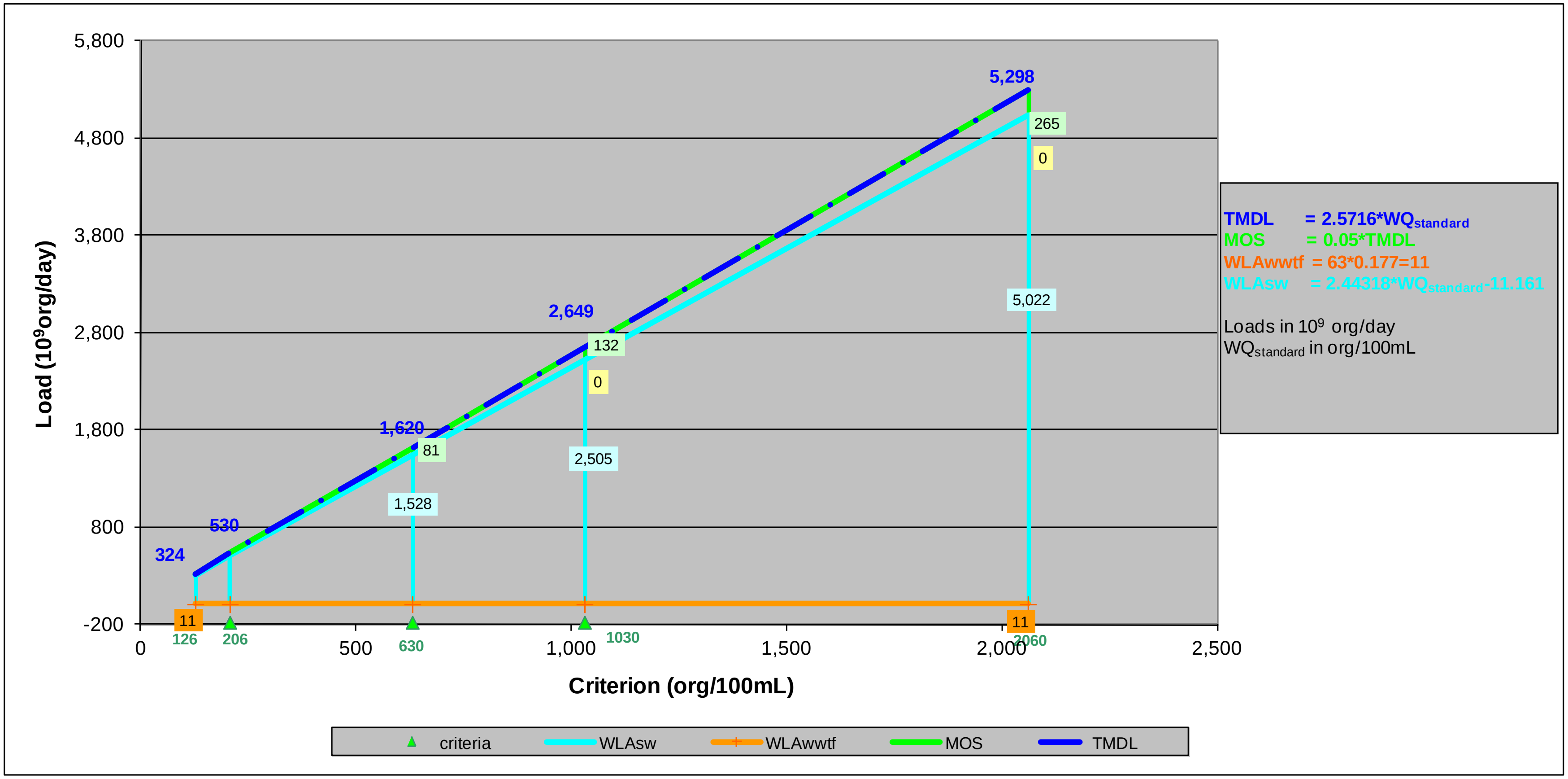

Figure 5-8 Allocation Loads for AU 1007U_01 as a Function of WQ Criteria

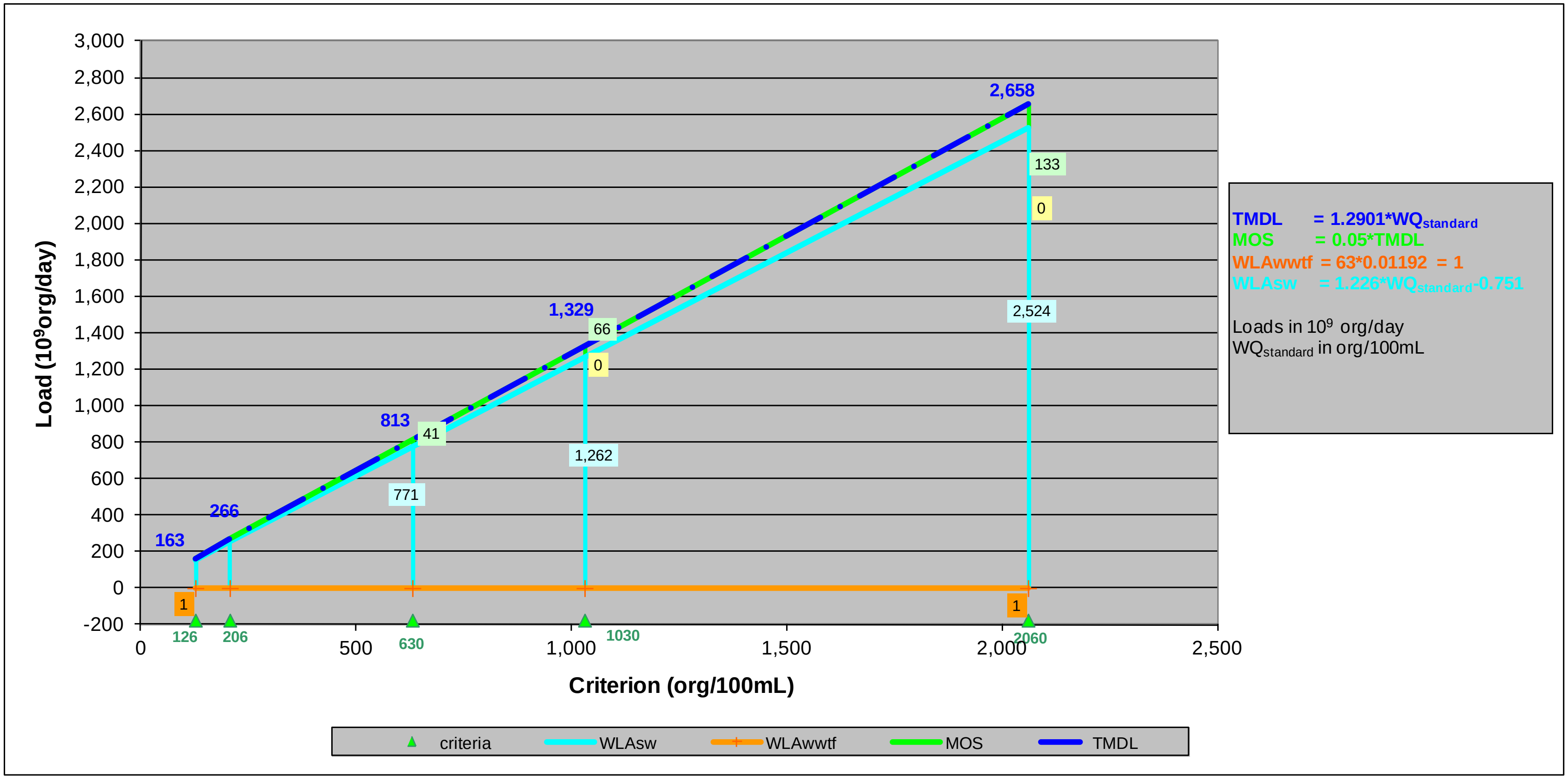

Figure 5-9 Allocation Loads for AU 1007S_01 as a Function of WQ Criteria

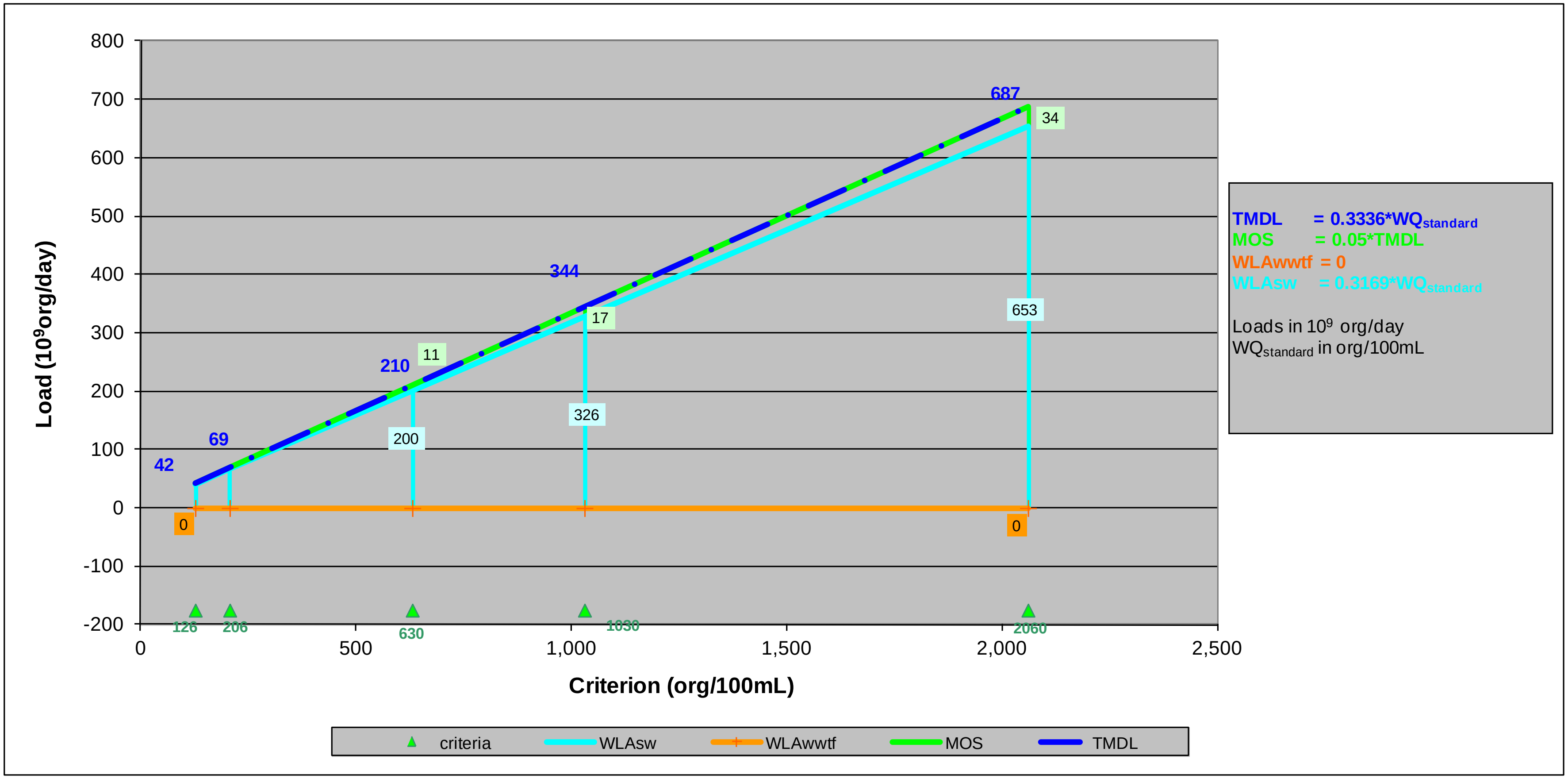

Figure 5-10 Allocation Loads for AU 1007V_01 as a Function of WQ Criteria

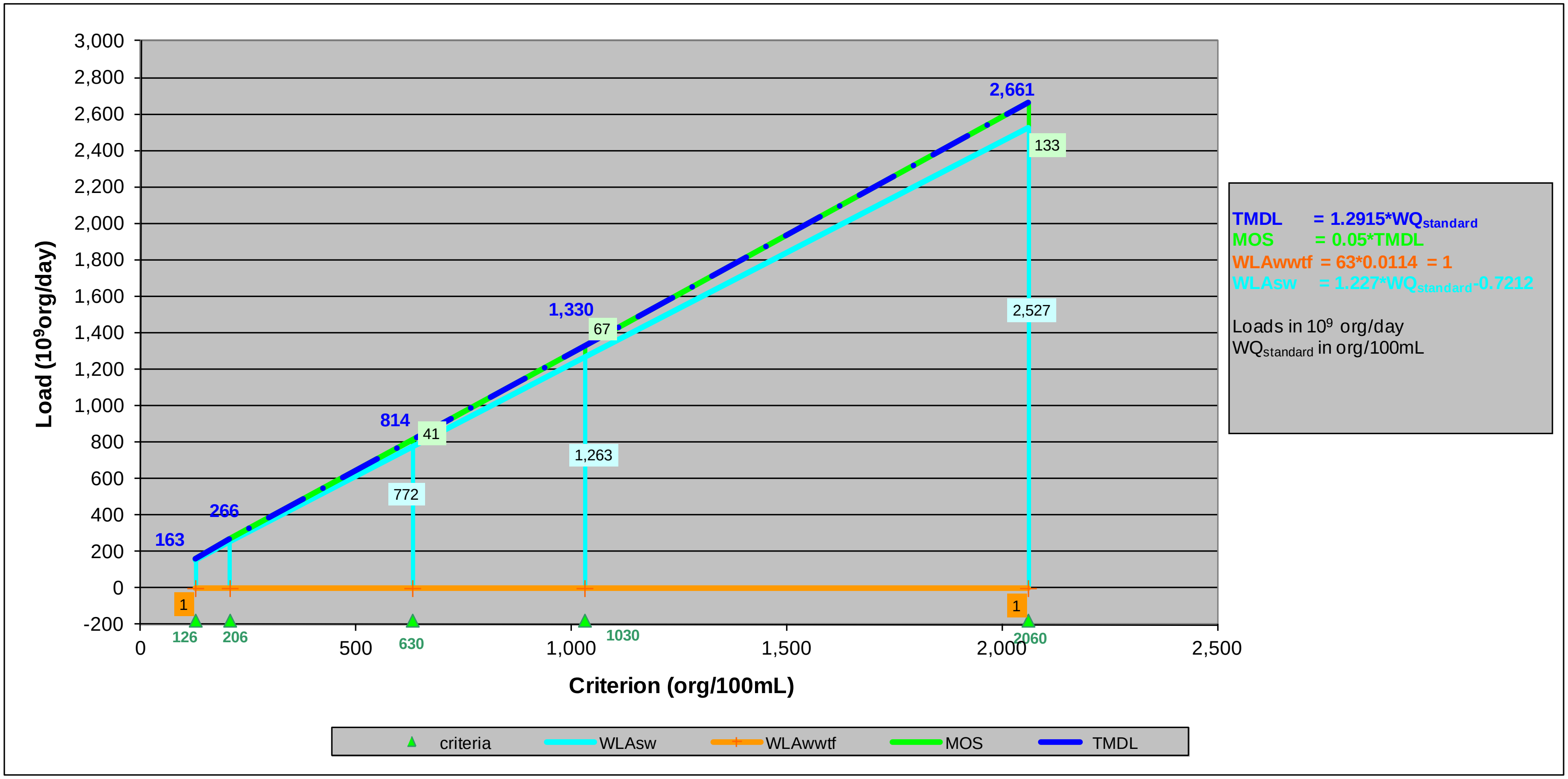

Figure 5-11 Allocation Loads for AU 1017C_01 as a Function of WQ Criteria

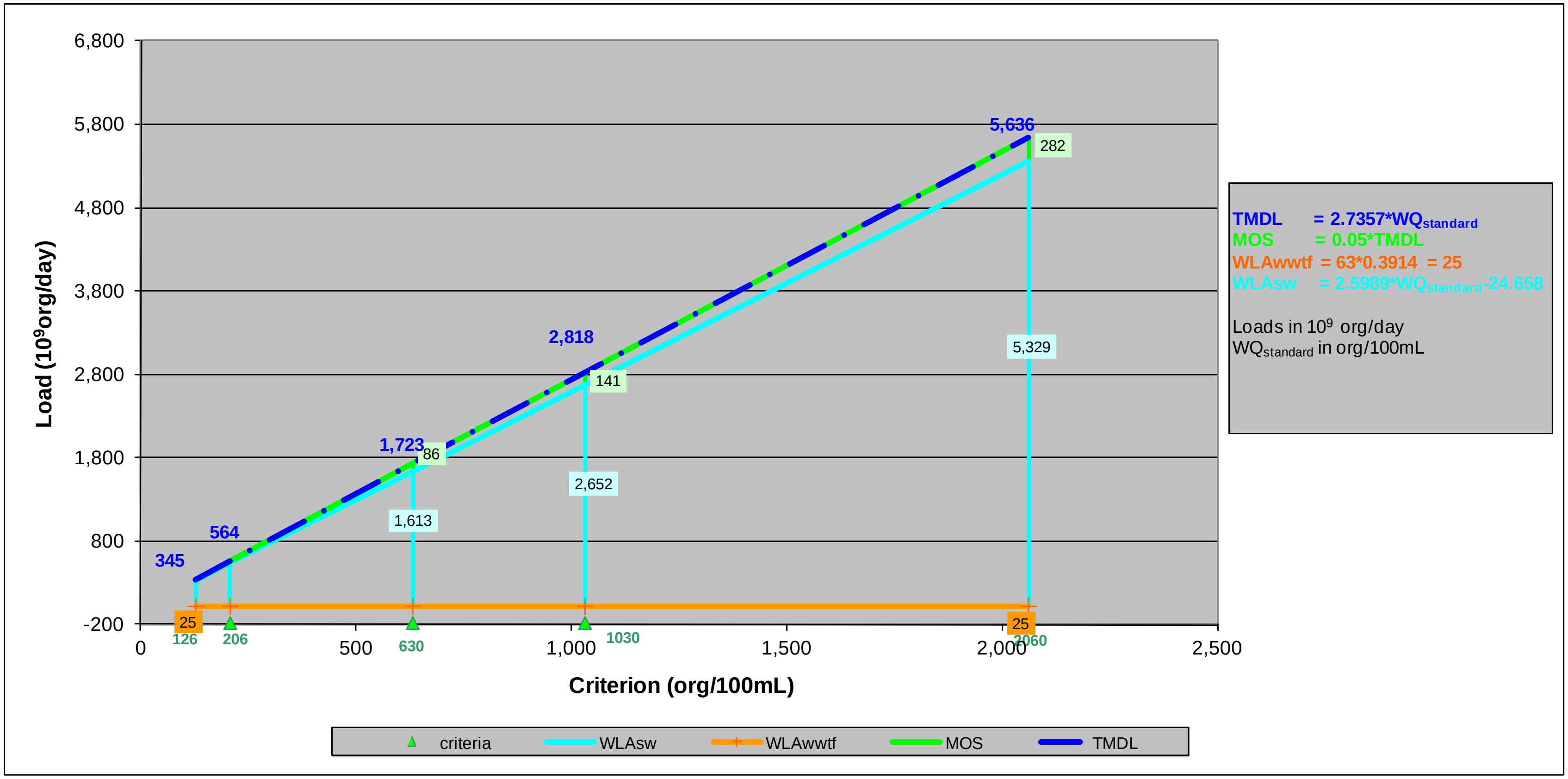

Figure 5-12 Allocation Loads for AU 1007A_01 as a Function of WQ Criteria

CHAPTER 6
PUBLIC PARTICIPATION

The Houston-Galveston Area Council is providing coordination for public participation in this project. To obtain public input on these TMDLs and the implementation phase, public meetings will be held. The meetings will introduce the TMDL process, identify the impaired segments and the reason for the impairment, review historical data, describe potential sources of bacteria within the watershed, and present preliminary load allocations. In addition, the meetings will give TCEQ the opportunity to solicit input from all interested parties within the Study Area.

CHAPTER 7
REFERENCES

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APPENDIX A
AMBIENT WATER QUALITY BACTERIA DATA – 1999 TO 2011

APPENDIX B
USGS FLOW DATA

APPENDIX C
DISCHARGE MONITORING REPORTS – 1997 TO 2009